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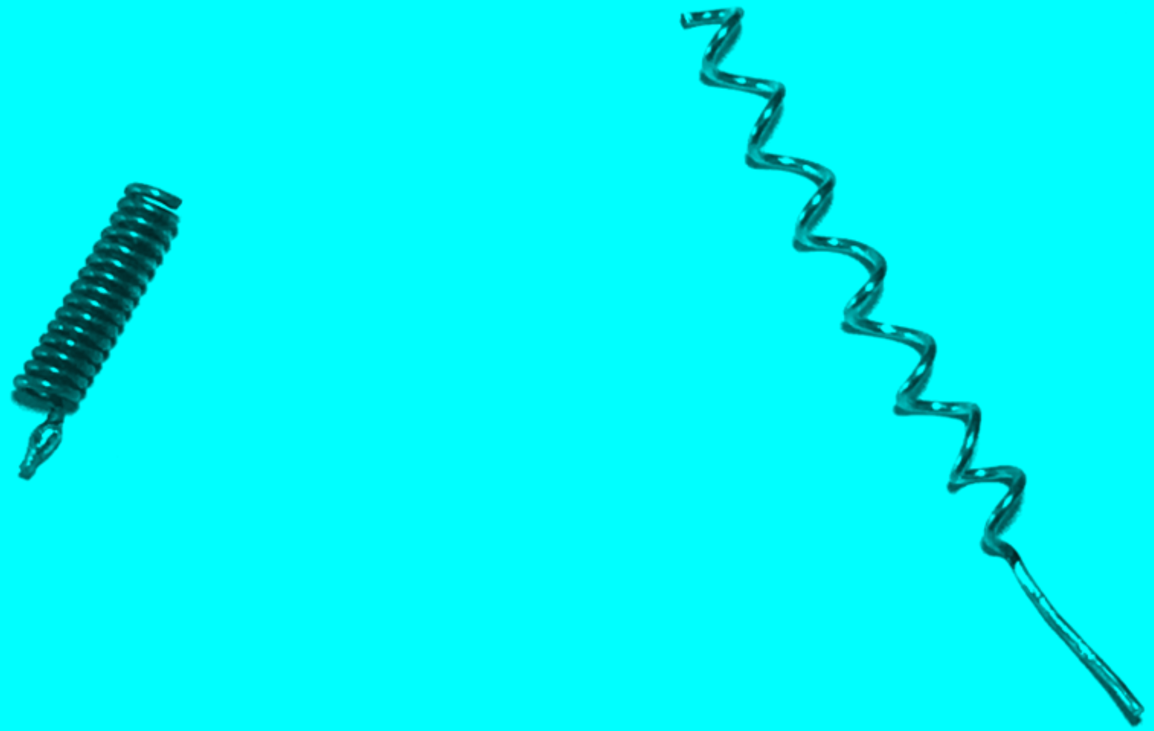
LORA / LORAWAN TUTORIAL 45

Normal Mode Helical Antenna



v1.0.0

INTRO

- In this tutorial I will explain what a normal mode helical antenna is.

ATTENTION

- **The antennas built in this tutorial are intended for test and educational purpose and should be used indoors.**

- **The antennas are constructed in such a way so it can be easily disassembled and its parts can be re-used in other antenna projects.**

- **The antennas are not properly constructed and the antenna performance can be improved by using better materials, parts or another way of construction.**

HELICAL ANTENNAS

- In the past I named the helical antennas, coil antennas but this is not correct.

How to create a copper 868MHz coil antenna

Mobilefish.com • 10K views • 2 years ago

This movie describes how to create a copper 868MHz coil antenna based on the antenna design found at: http://www.professor.com ...

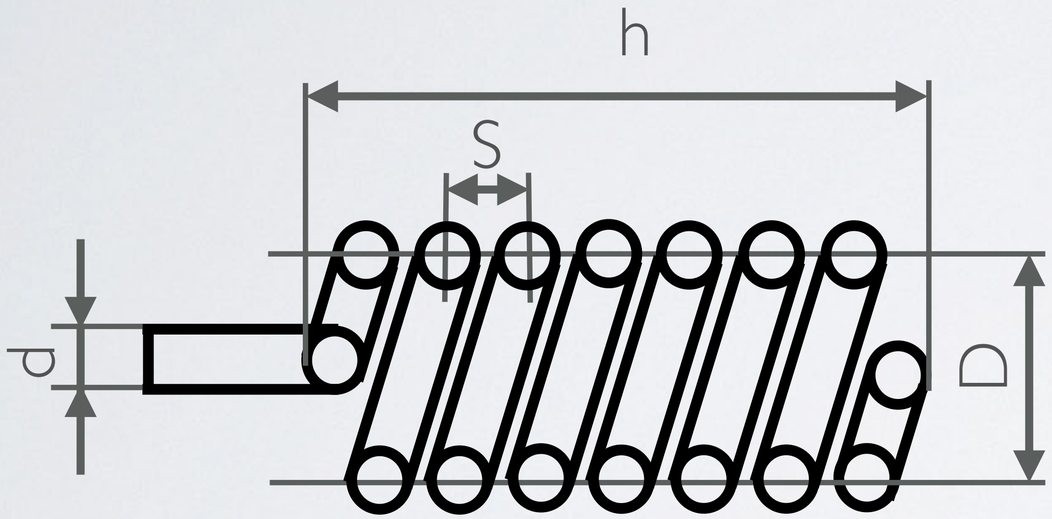
https://youtu.be/5d2GJOVMWSs

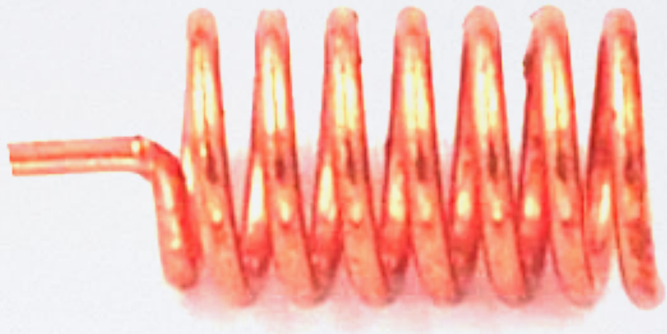
- In literature these antennas are called **helical antennas** and are invented by John D. Kraus.

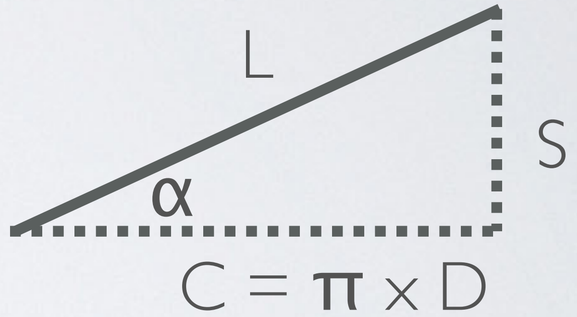
- Helical antennas can be made to operate in one of two ways:
  - normal mode or
  - axial mode.

HELICAL ANTENNAS

Equations to calculate h and L_w

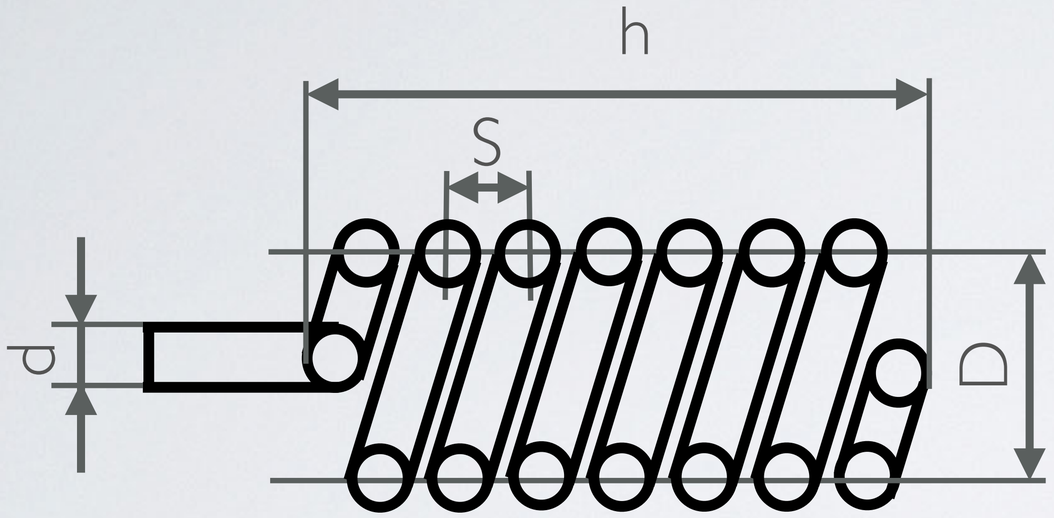


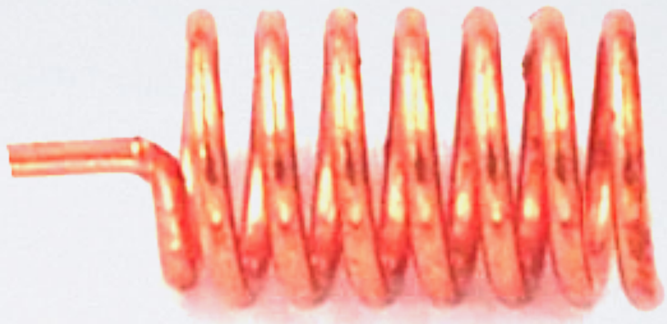


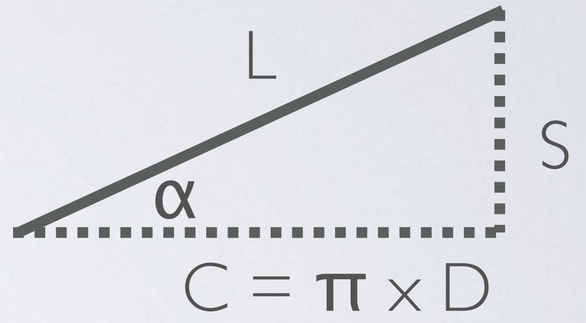


D = diameter of helix (center-to-center)
C = circumference of helix = π x D
d = wire diameter
α = pitch angle = $\tan^{-1}(S/C)$

HELICAL ANTENNAS







S = pitch, the spacing between turns (center-to-center)
S = C x tan(α)

L = length of **one** uncoiled turn = $\sqrt{S^2 + C^2}$

N = number of turns

L_w = total length of the wire when the helix is completely uncoiled (L_w = N x L)

h = height (h = N x S)

HELICAL ANTENNAS

- It is very useful to know the height (h) and the total length of the wire when the helix is completely uncoiled (Lw).
  - If you want to build your own helical antenna, you need to know how much wire you need (Lw).
  - If you model the antenna in the 4NEC2 program you might get warning or error messages. Often these messages relates to the ratio "segment length to radius". The helical segment length = Lw / number of segments
  - The height is important if you want to know if the antenna will fit inside your project box (aka electronic enclosure).
- Spreadsheet: https://www.mobilefish.com/download/lora/helical.ods

AXIAL MODE HELICAL ANTENNA

- In axial mode, the antenna is **circular polarised** and radiates in the direction of the helix. These antennas are **directional**.

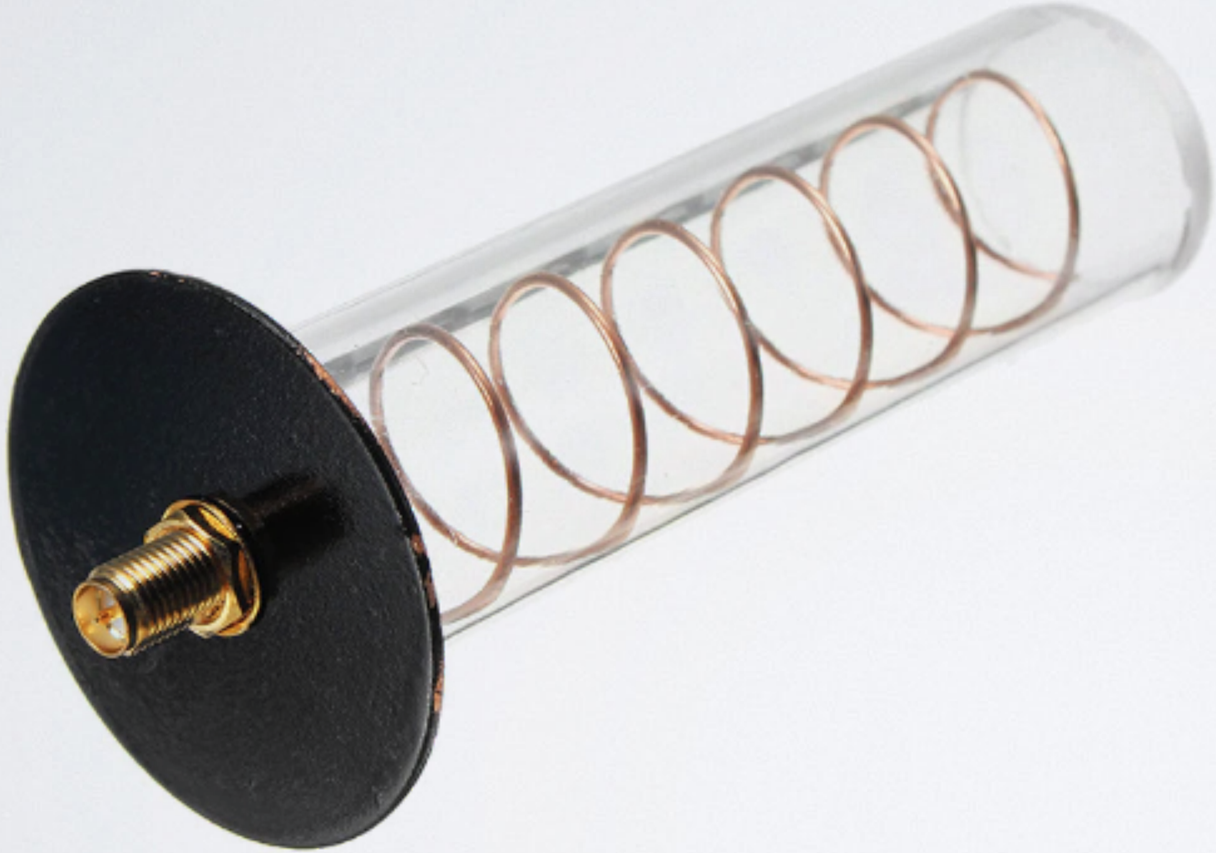
- The diameter (D) and pitch (S) of these helical antennas are **roughly comparable** to the wavelength.

- As far as I know all LoRaWAN gateways are using linear polarised antennas. Therefor end nodes using axial mode helical antennas makes no sense.

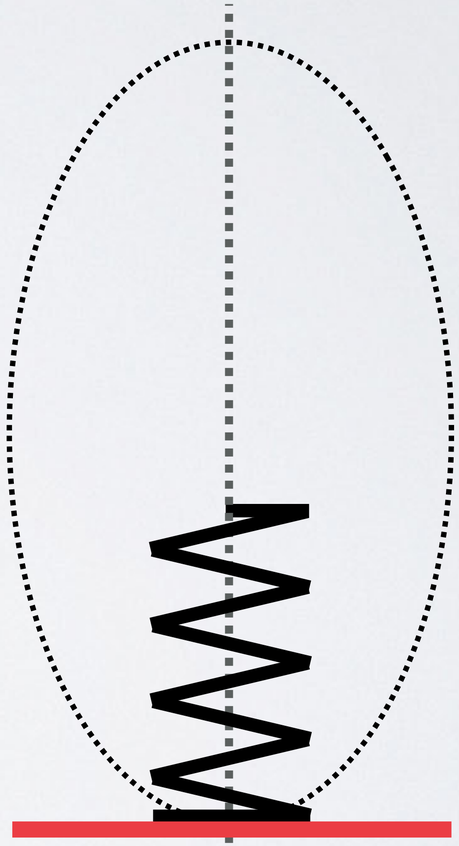
- In this tutorial I will only focus on the normal mode helical antennas.

AXIAL MODE HELICAL ANTENNA

Example axial mode helical antenna



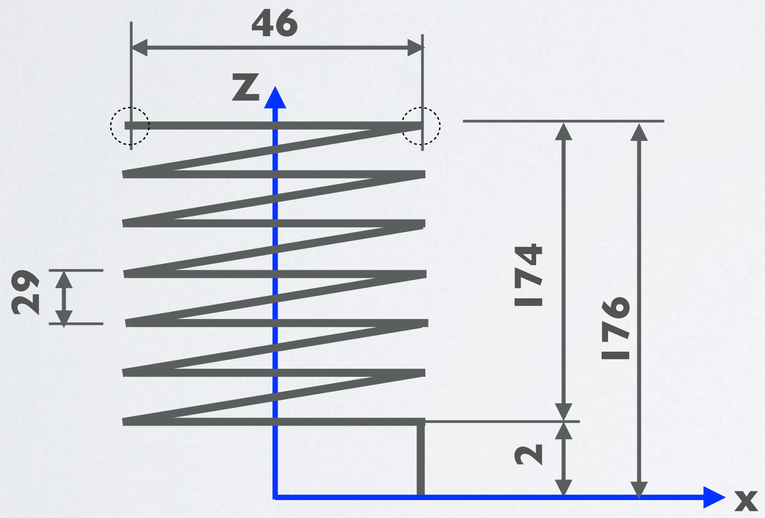
Radiation pattern
Circular polarised
Not on scale



AXIAL MODE HELICAL ANTENNA

- As a demonstration I created an axial mode helical antenna in the 4NEC2 program. This axial mode helical antenna is NOT intended for LoRa radios but for radio systems using 2.45 GHz.

- Axial mode helical antenna card deck: https://www.mobilefish.com/download/lora/axial_mode_helical_2.45ghz.nec.txt

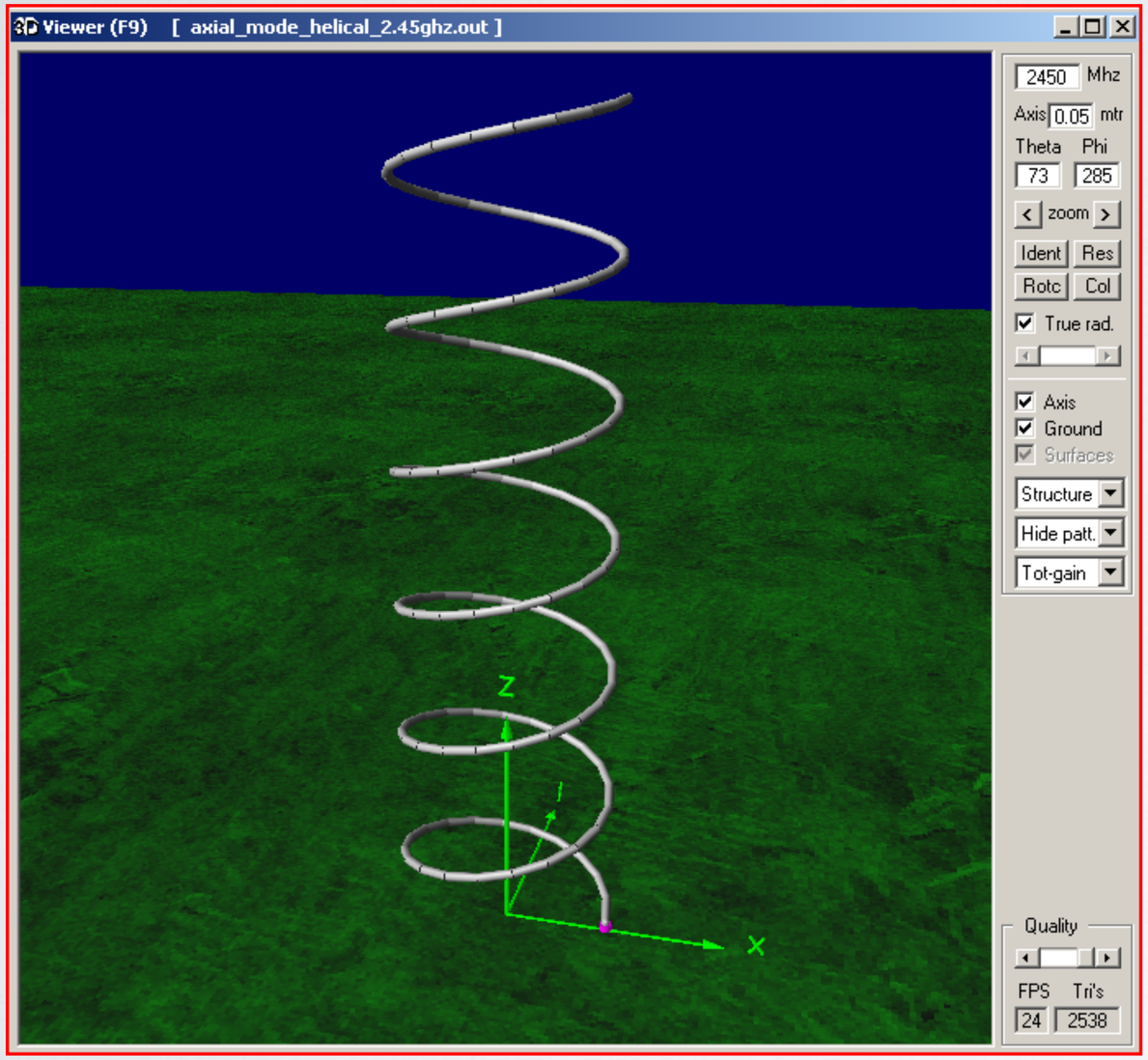


Units in mm

Wire diameter = 2 mm
Number of turns = 6
f = 2.45 GHz
Material: copper

Drawing not to scale

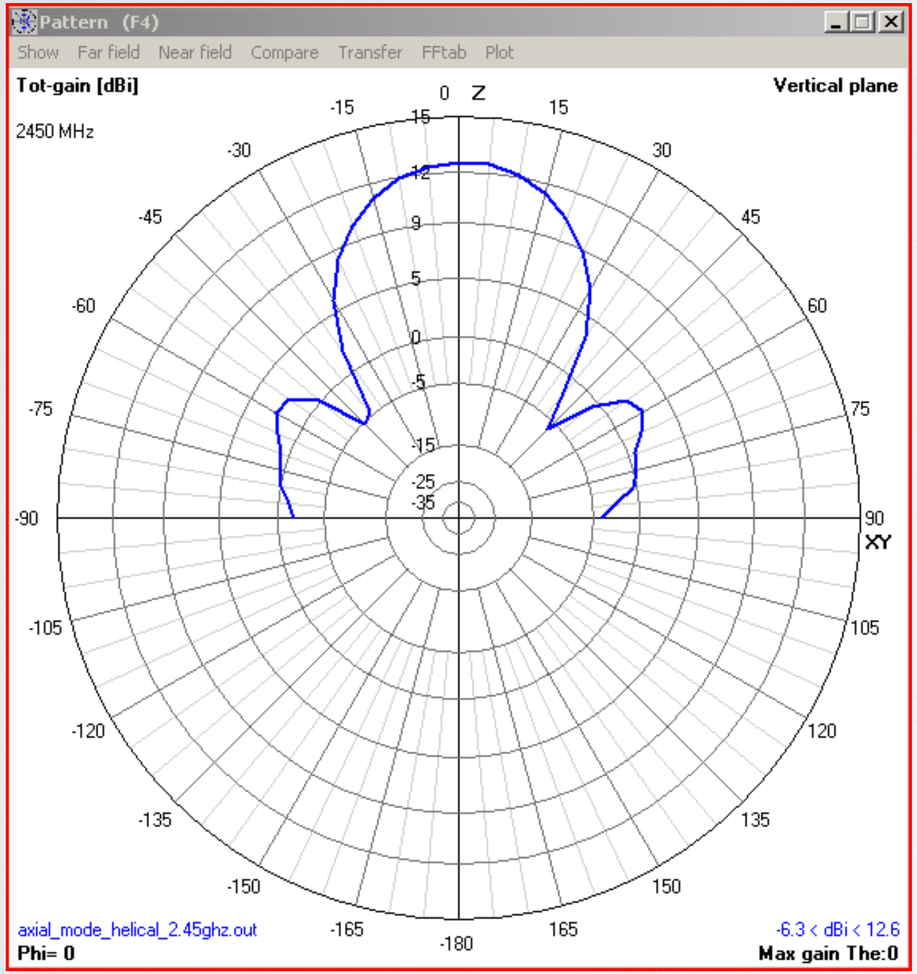
AXIAL MODE HELICAL ANTENNA

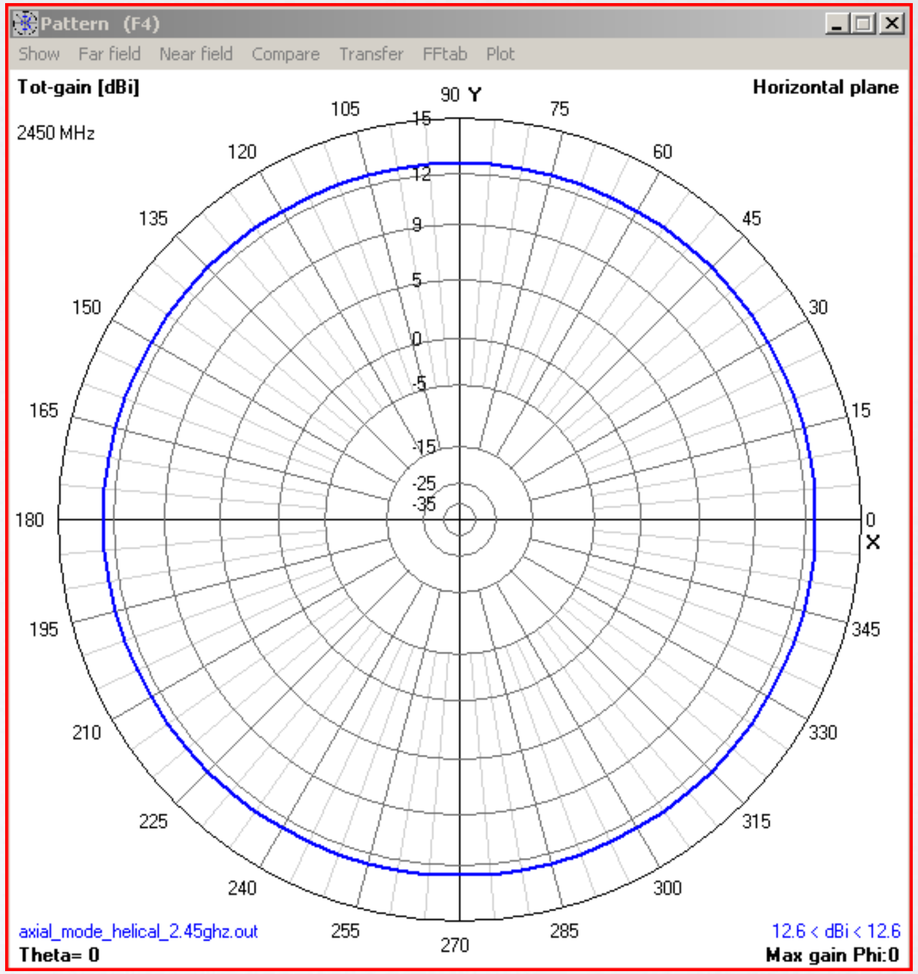


Created in 4NEC2

AXIAL MODE HELICAL ANTENNA

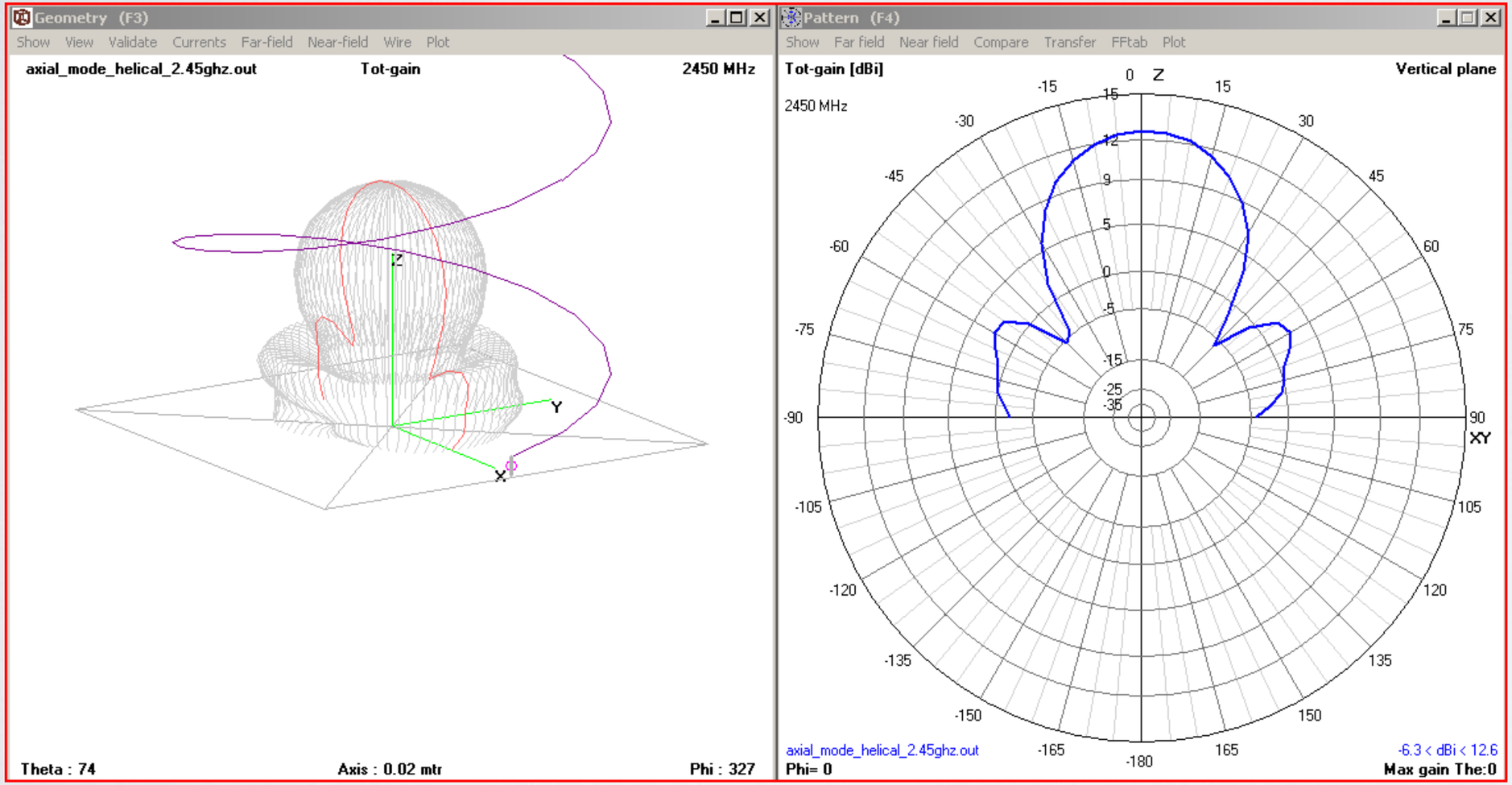
- Ground: Perfect ground (= perfectly conducting ground)



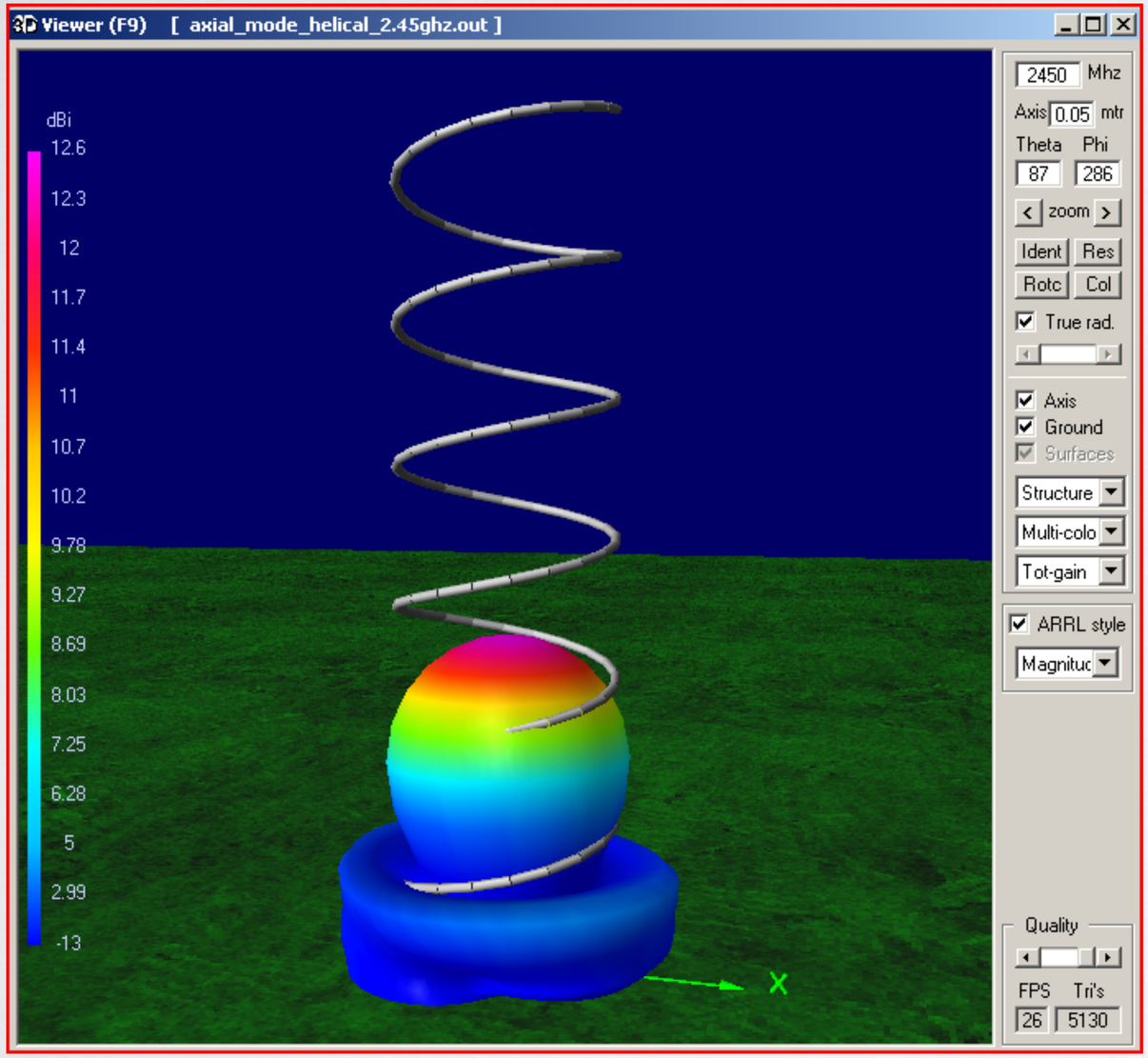


AXIAL MODE HELICAL ANTENNA

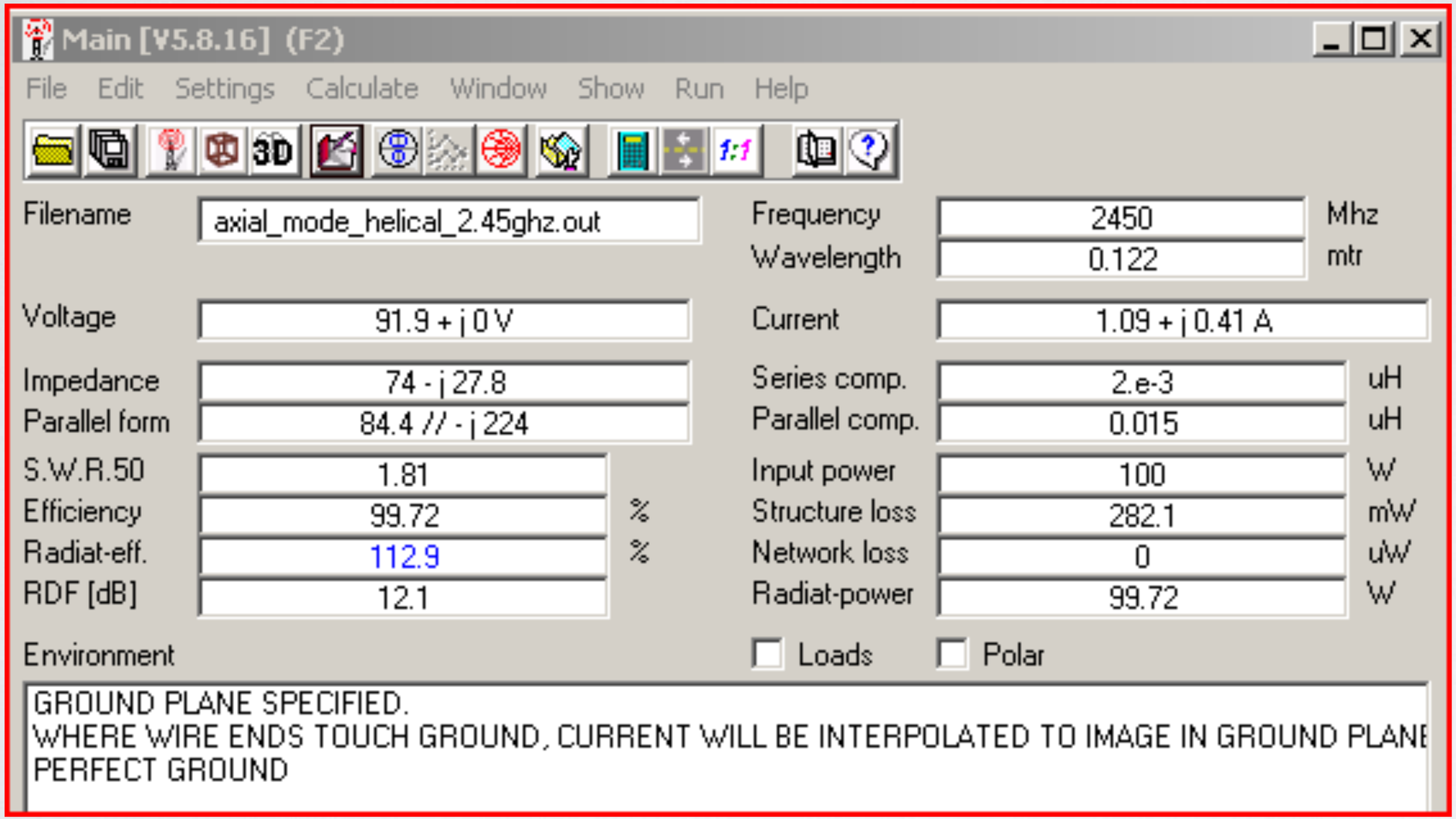
- Ground: Perfect ground (= perfectly conducting ground)



AXIAL MODE HELICAL ANTENNA



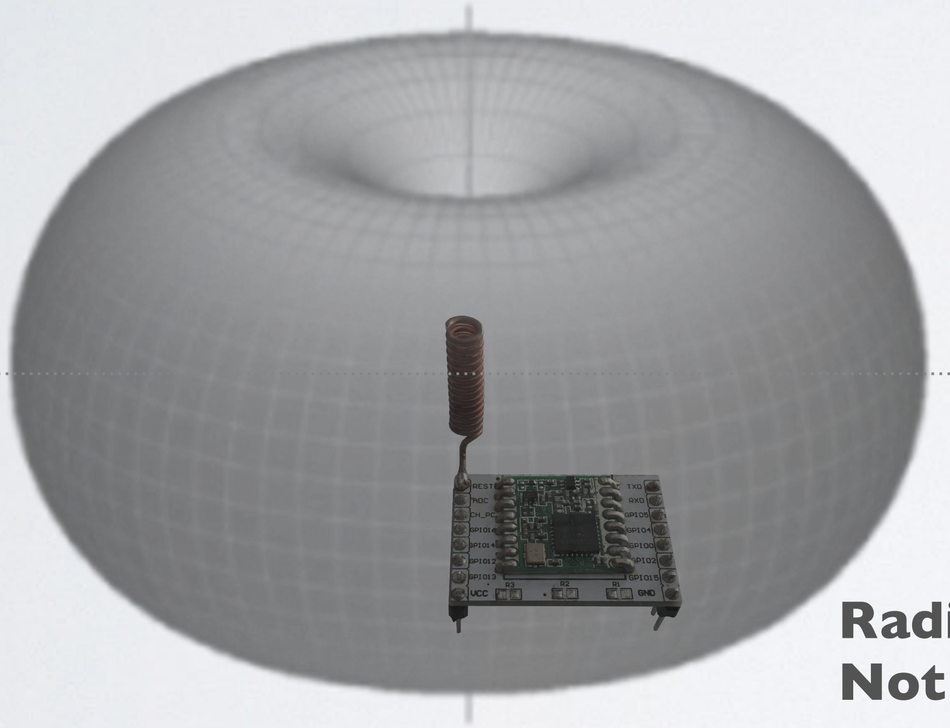
AXIAL MODE HELICAL ANTENNA



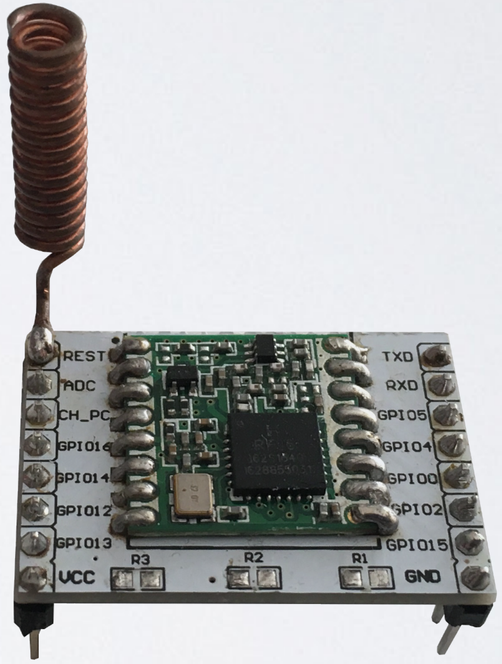
VSWR=1.81

NORMAL MODE HELICAL ANTENNA

- In normal mode, the antenna behaves like a monopole antenna (see tutorial 42) but are smaller in size and produces an **omnidirectional** radiation pattern, and is **linear polarised.**



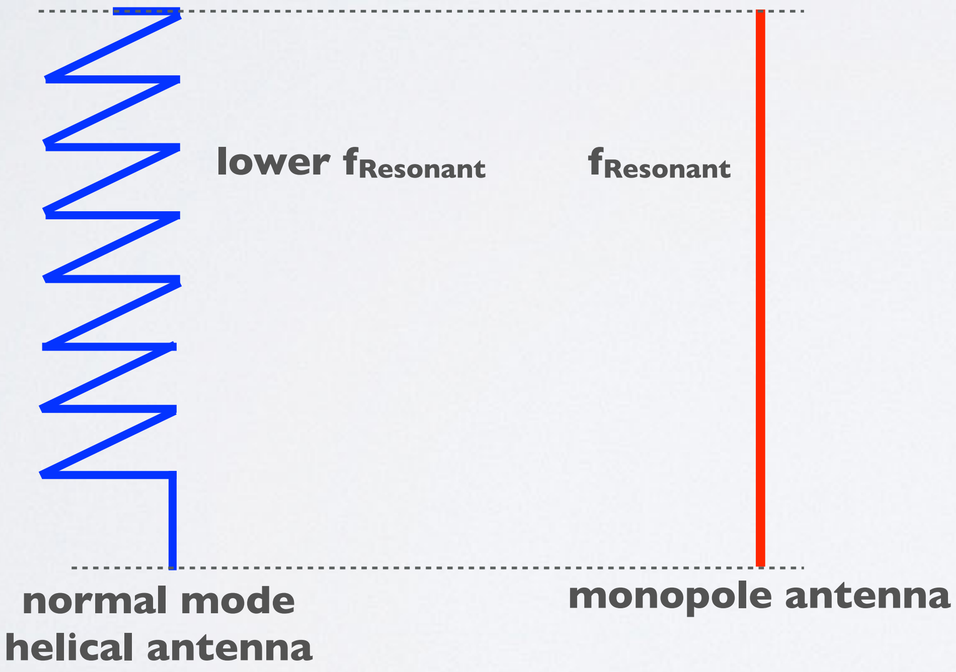
Radiation pattern
Not on scale



NORMAL MODE HELICAL ANTENNA

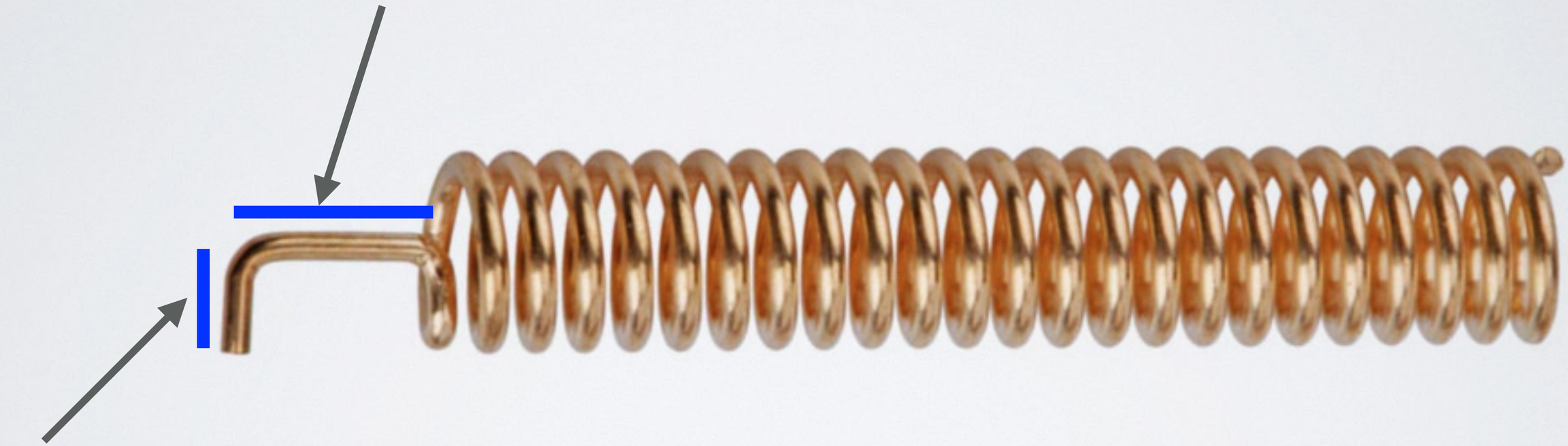
- The diameter (D) and pitch (S) of these helical antennas are **small** in comparison to the wavelength.

- The normal mode helical antenna has a lower resonant frequency than its comparable sized monopole counterpart.



NORMAL MODE HELICAL ANTENNA

This piece is part of the normal mode helical antenna.
DO NOT SHORTEN ITS LENGTH!



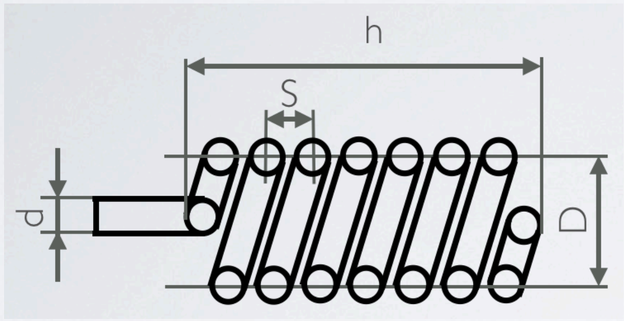
Solder the antenna on the PCB at this piece.

NORMAL MODE HELICAL ANTENNA

- A helical antenna is in normal mode when the circumference and the spacing is within this shaded area.

$$\pi D_\lambda = \frac{\pi D}{\lambda}$$

$$S_\lambda = \frac{S}{\lambda}$$



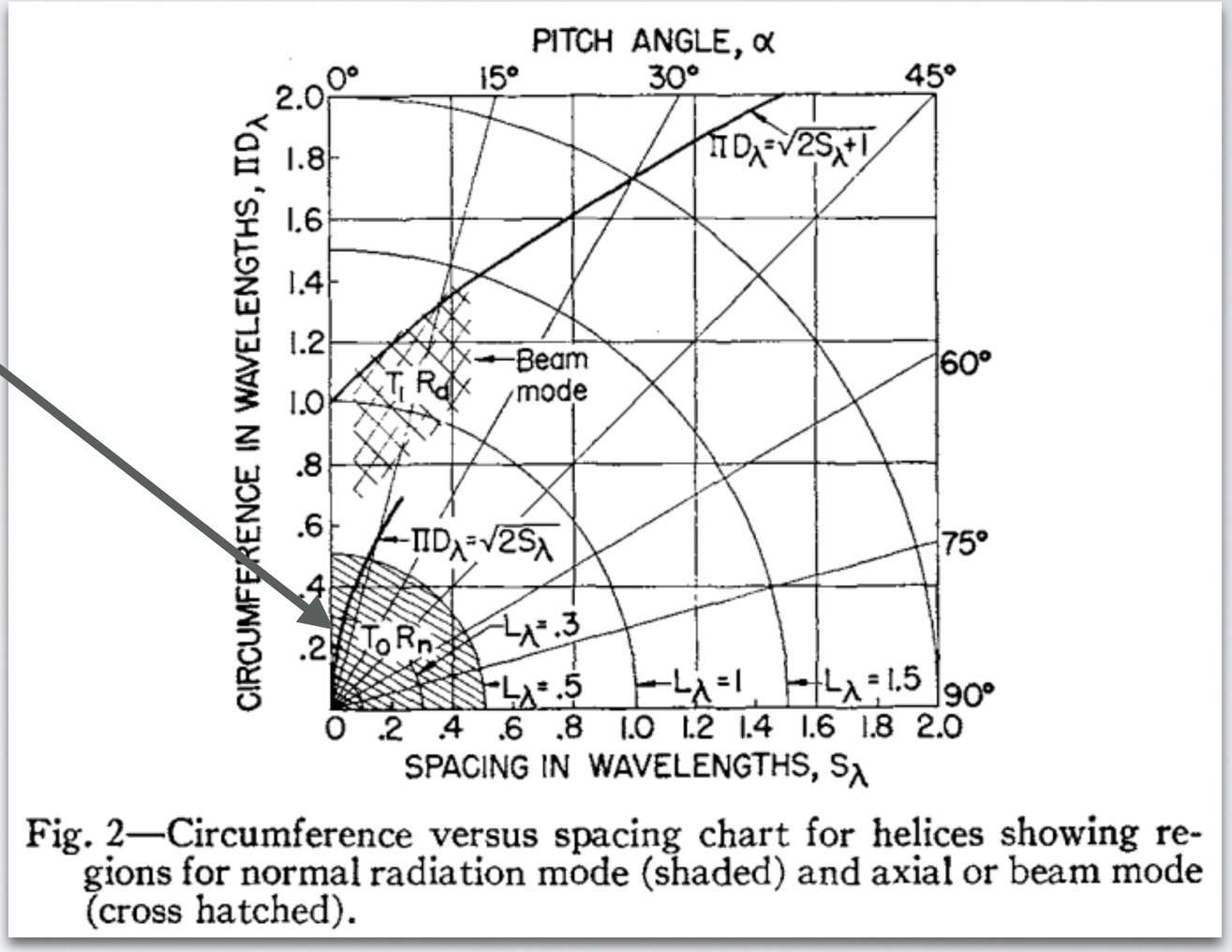


Fig. 2—Circumference versus spacing chart for helices showing regions for normal radiation mode (shaded) and axial or beam mode (cross hatched).

Source:
John D. Kraus, The Helical Antenna, Proceedings of the IRE, 1949

ORIGINAL NORMAL MODE HELICAL ANTENNA

- As mentioned earlier I created a YouTube video:
  "How to create a copper 868MHz coil antenna"
  https://youtu.be/5d2GJOVMWSs

- The normal mode helical antenna demonstrated in the YouTube video is based on:
  http://www.professor.com.tw/upLoad/product/month_1402/20140225174244730 2.pdf

- If the above mentioned link does not work, see:
  https://www.mobilefish.com/download/lora/normal_mode_helical_antenna_professor_technology.pdf

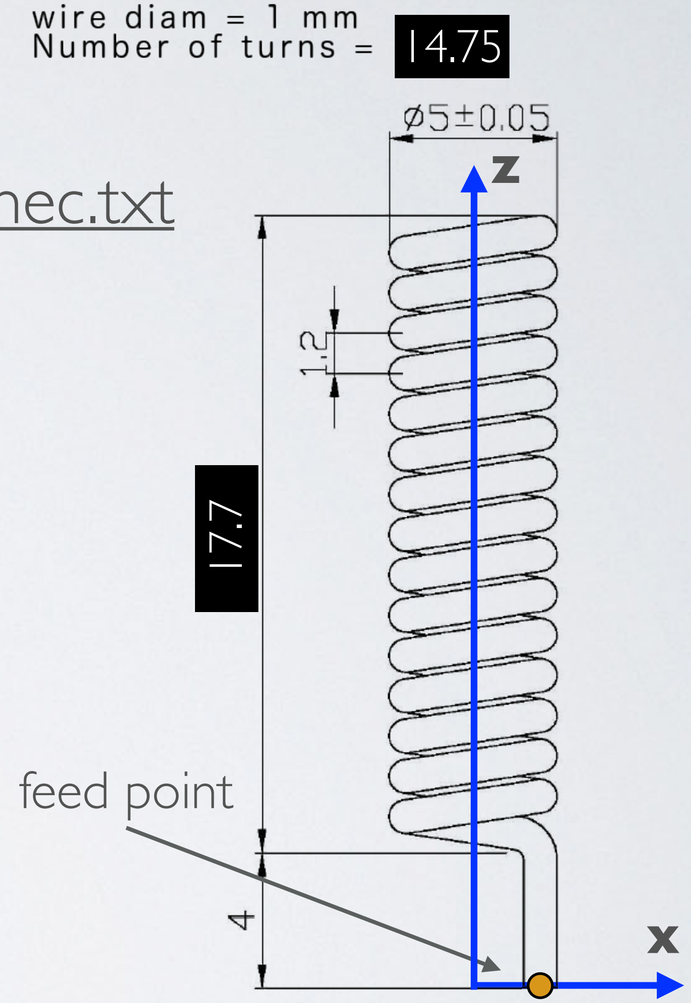
- Based on the above mentioned design I have created an antenna model in the 4NEC2 program.

ORIGINAL NORMAL MODE HELICAL ANTENNA

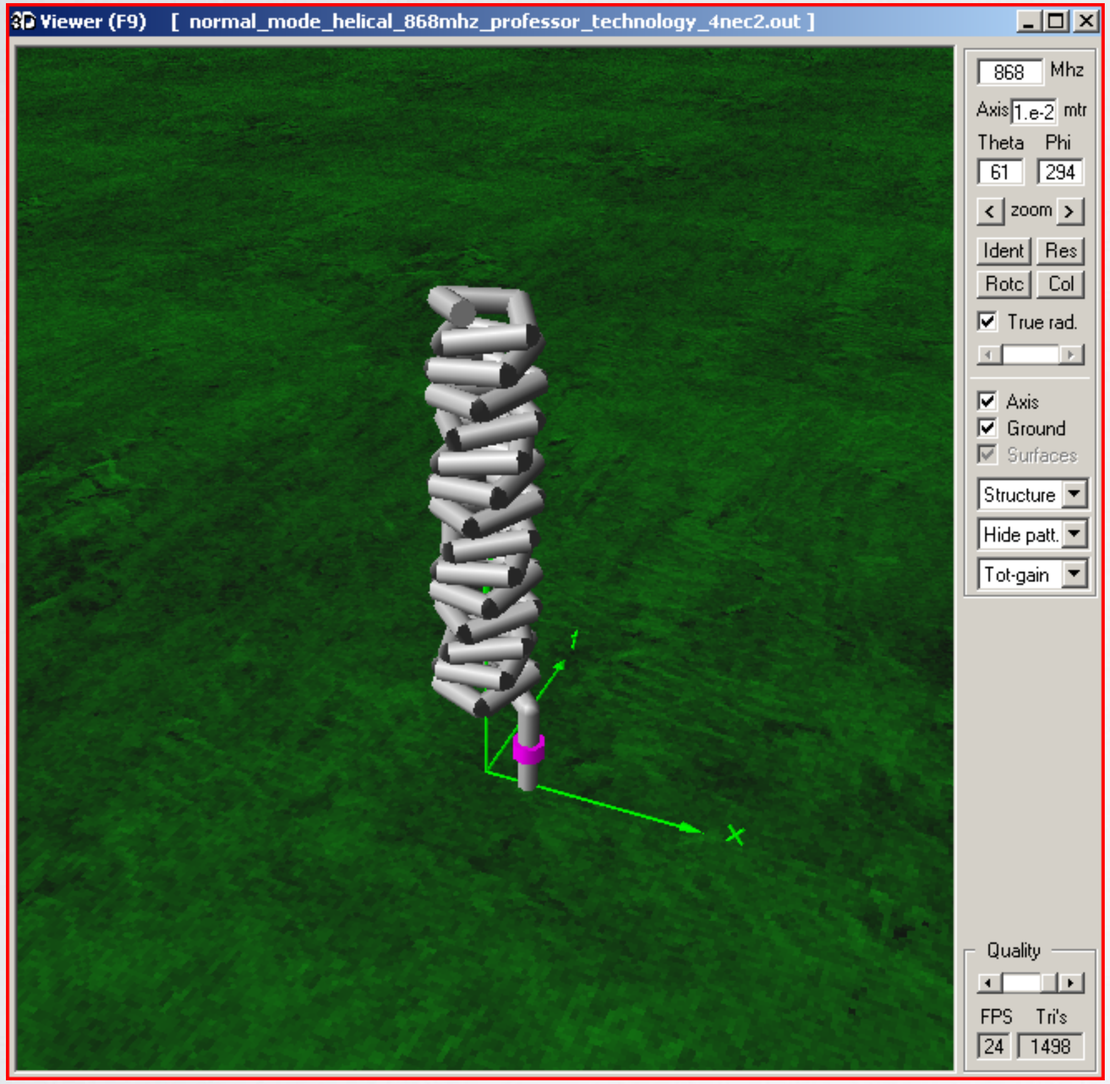
- 4NEC2 card deck:
  https://www.mobilefish.com/download/lora/normal_mode_helical_868mhz_professor_technology_4nec2.nec.txt

- I have made two changes to the original design:
  - I have removed the 4.9 mm solder wire.
  - The number of turns is 14.75. This corresponds with the drawing and the total height = 1.2 x 14.7 = 17.7

- The ground in the XY plane is **perfectly conducting.**



ORIGINAL NORMAL MODE HELICAL ANTENNA

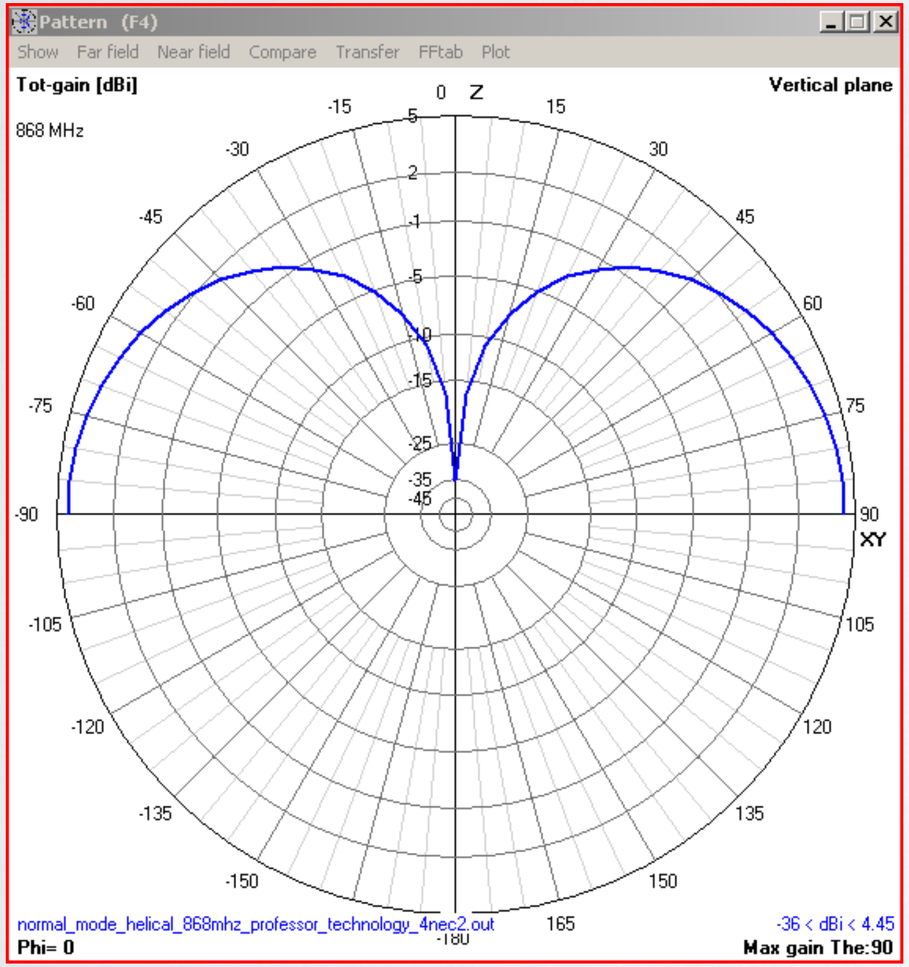


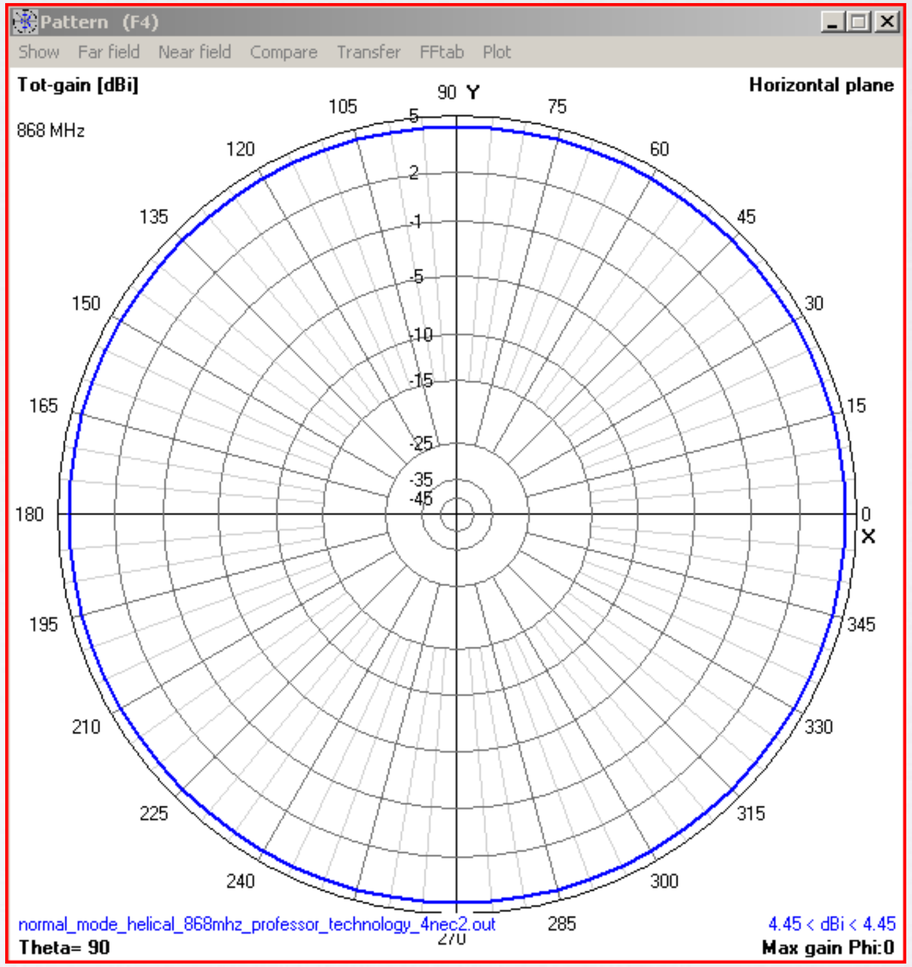
Note:
The number of segments for the helix is set to 55. If this value is increased I got warning messages.

Created in 4NEC2

ORIGINAL NORMAL MODE HELICAL ANTENNA

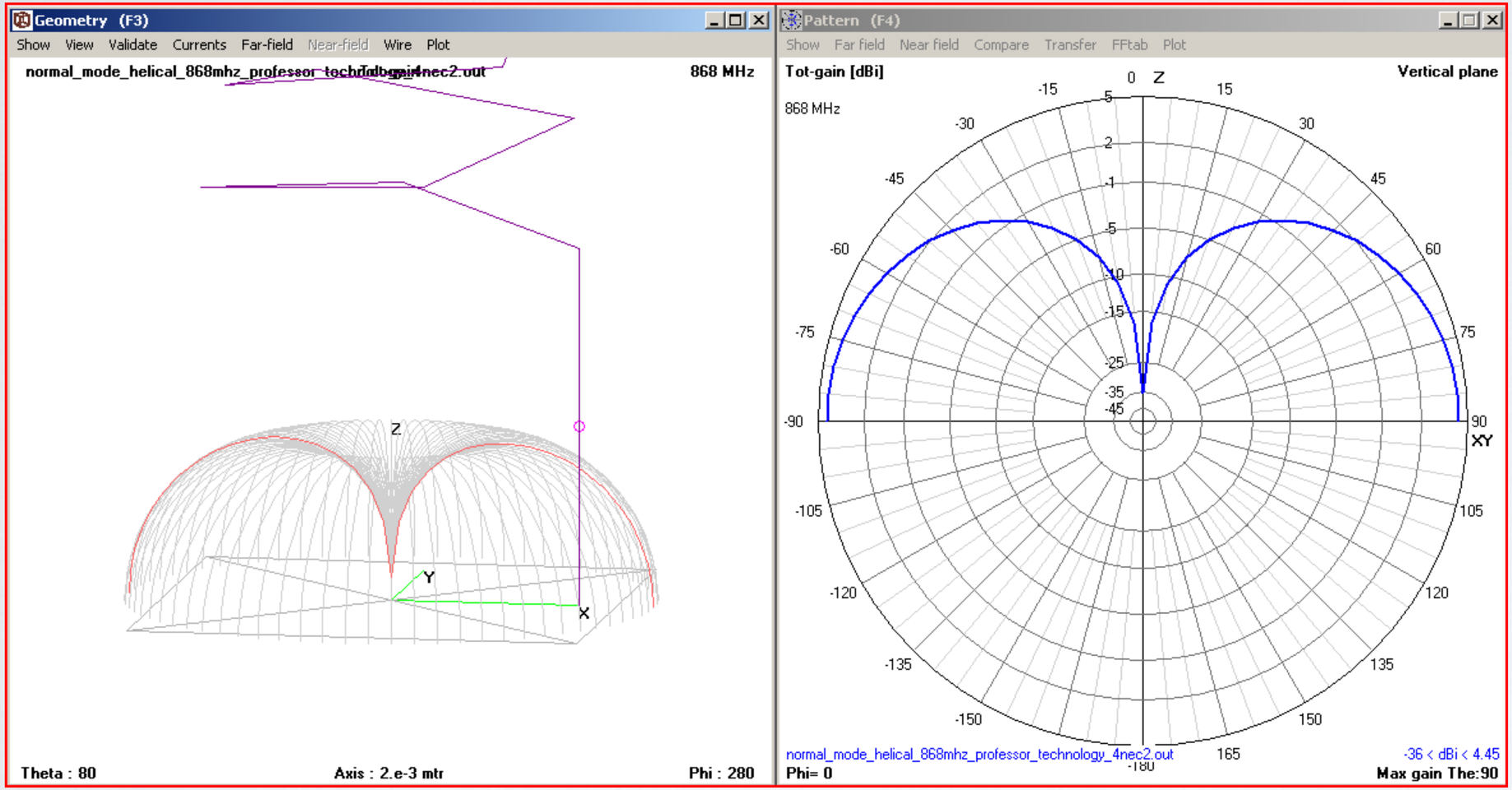
- Ground: Perfect ground (= perfectly conducting ground)



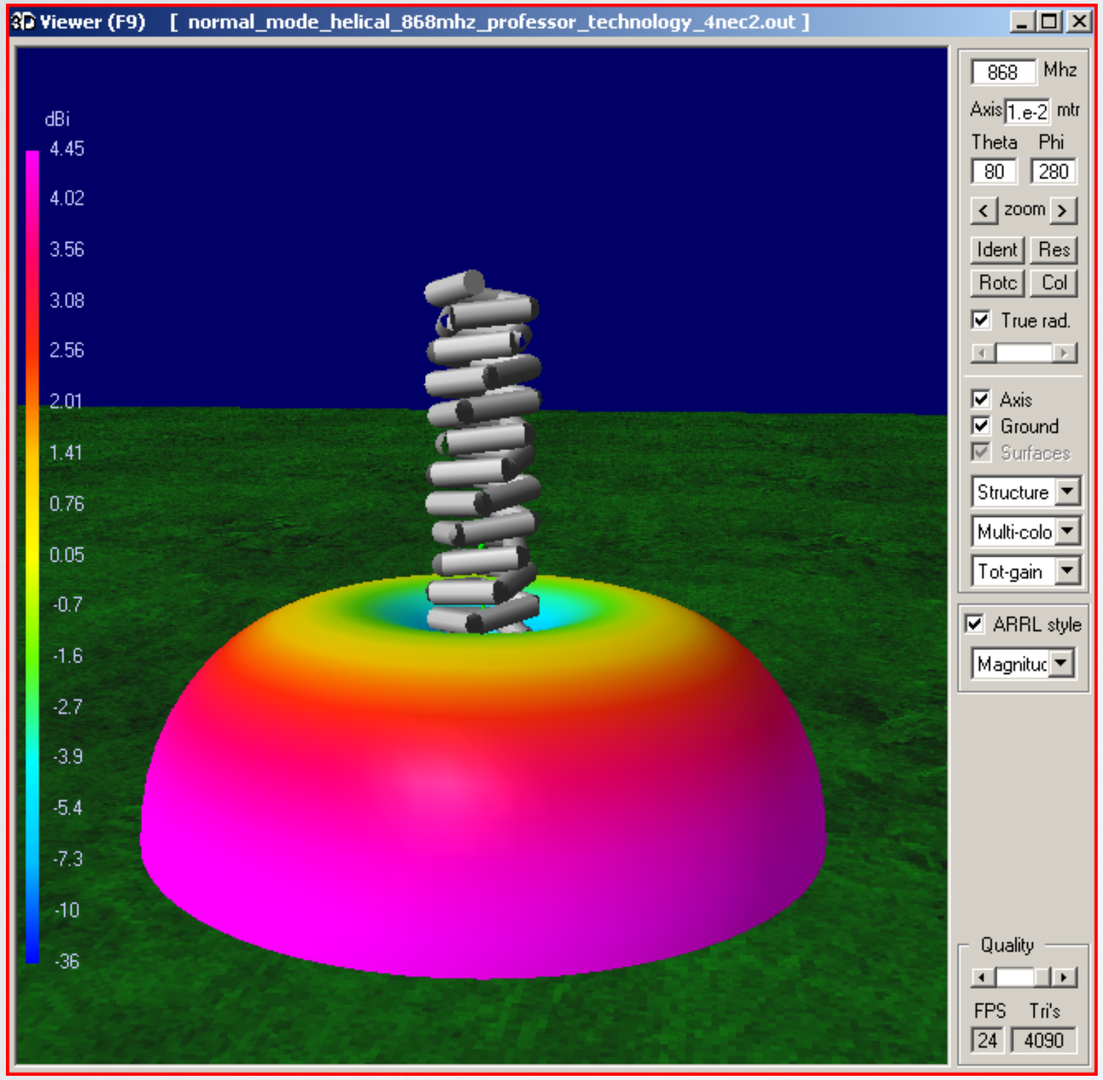


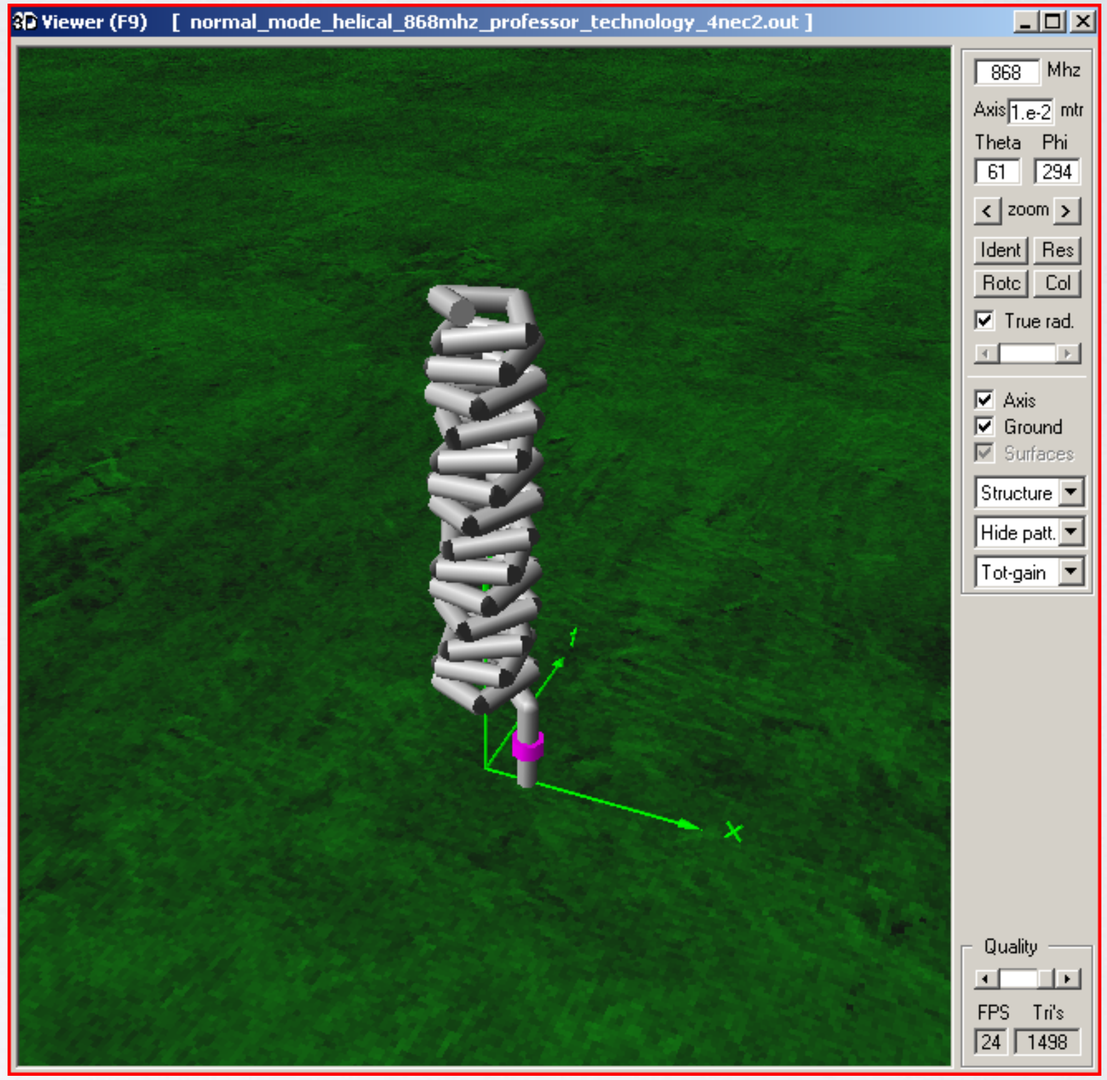
ORIGINAL NORMAL MODE HELICAL ANTENNA

- Ground: Perfect ground (= perfectly conducting ground)

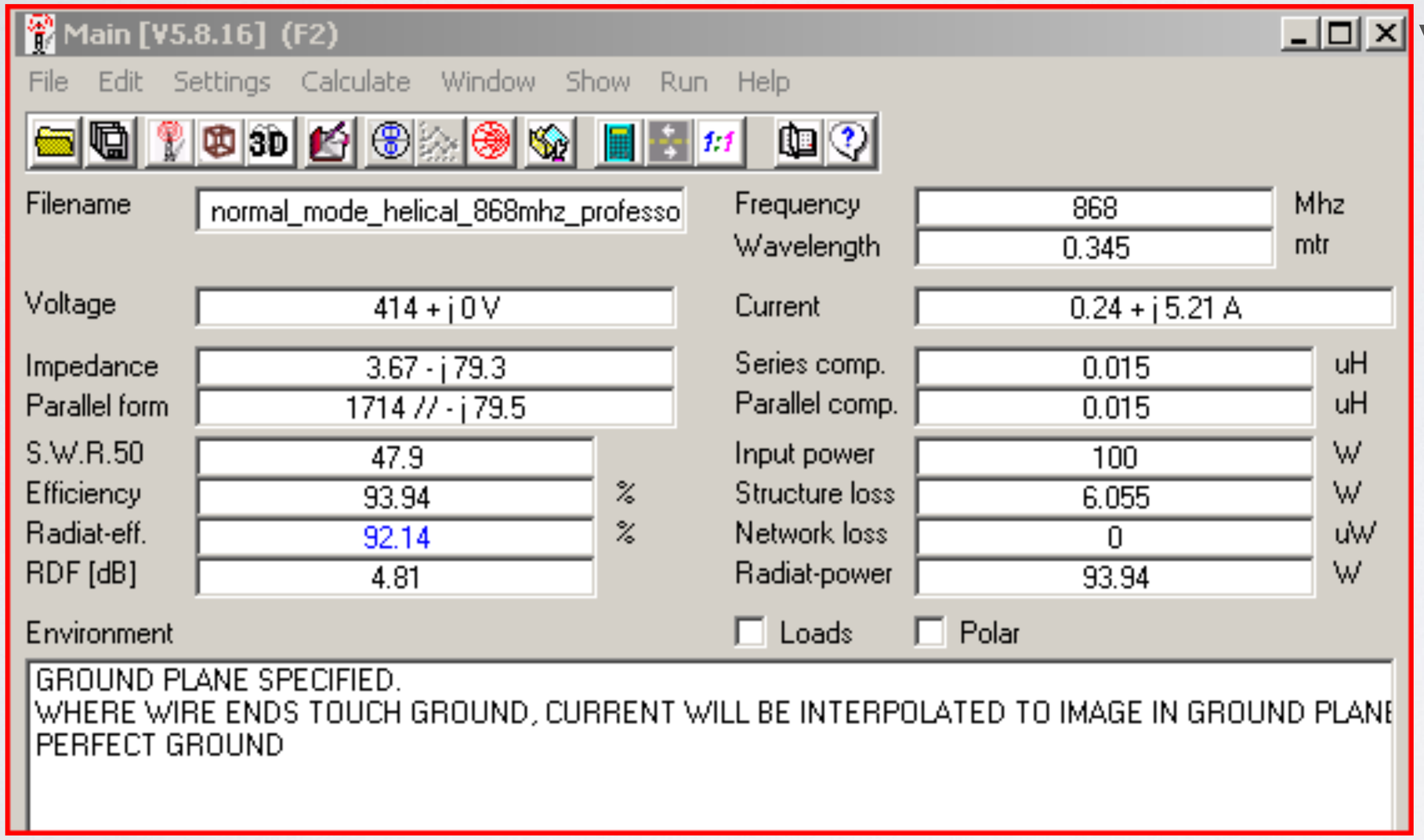


ORIGINAL NORMAL MODE HELICAL ANTENNA





ORIGINAL NORMAL MODE HELICAL ANTENNA



VSWR=47.9

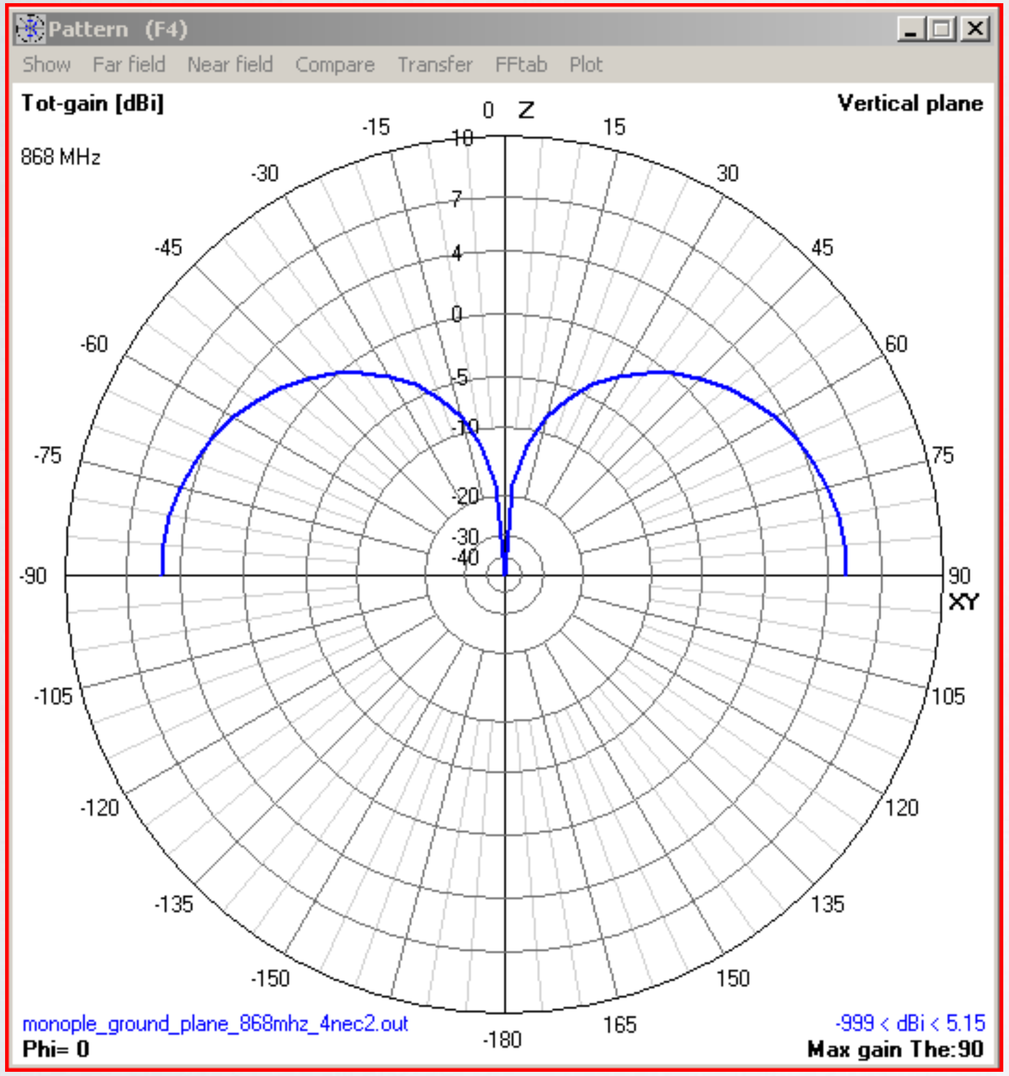
ORIGINAL NORMAL MODE HELICAL ANTENNA

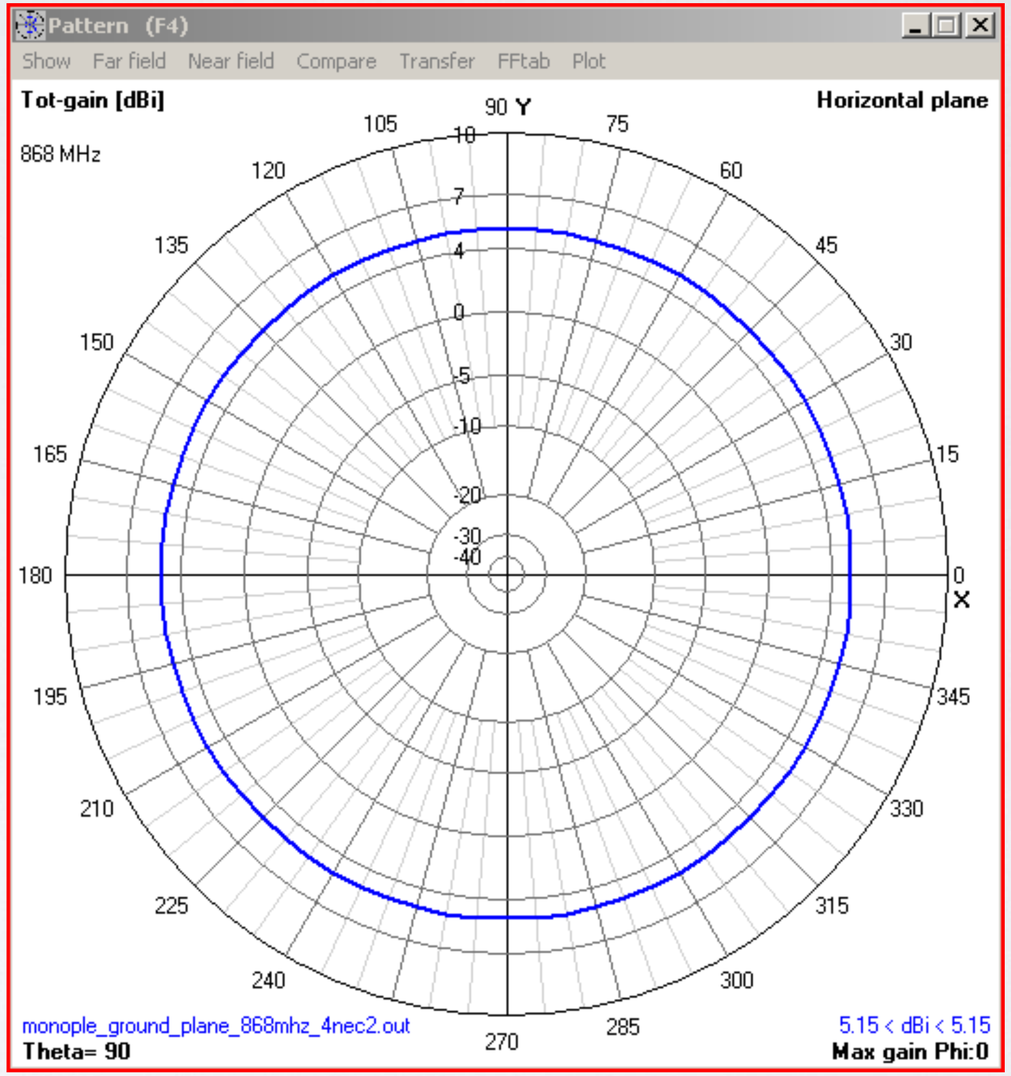
- Using the 4NEC2 antenna model software I got a VSWR of 47.9
  Unfortunately I could not figure out what was wrong with my antenna model.
  I could not get the VSWR below 2 without major variable changes.

- However in the original design, see:
  http://www.professor.com.tw/upLoad/product/month_1402/20140225174244730 2.pdf
  they were able to get a VSWR of 1.5

- Ignore the VSWR and focus on the radiation pattern. The point I am trying to make here is that the vertical and horizontal radiation pattern looks very similar to the monopole antenna.

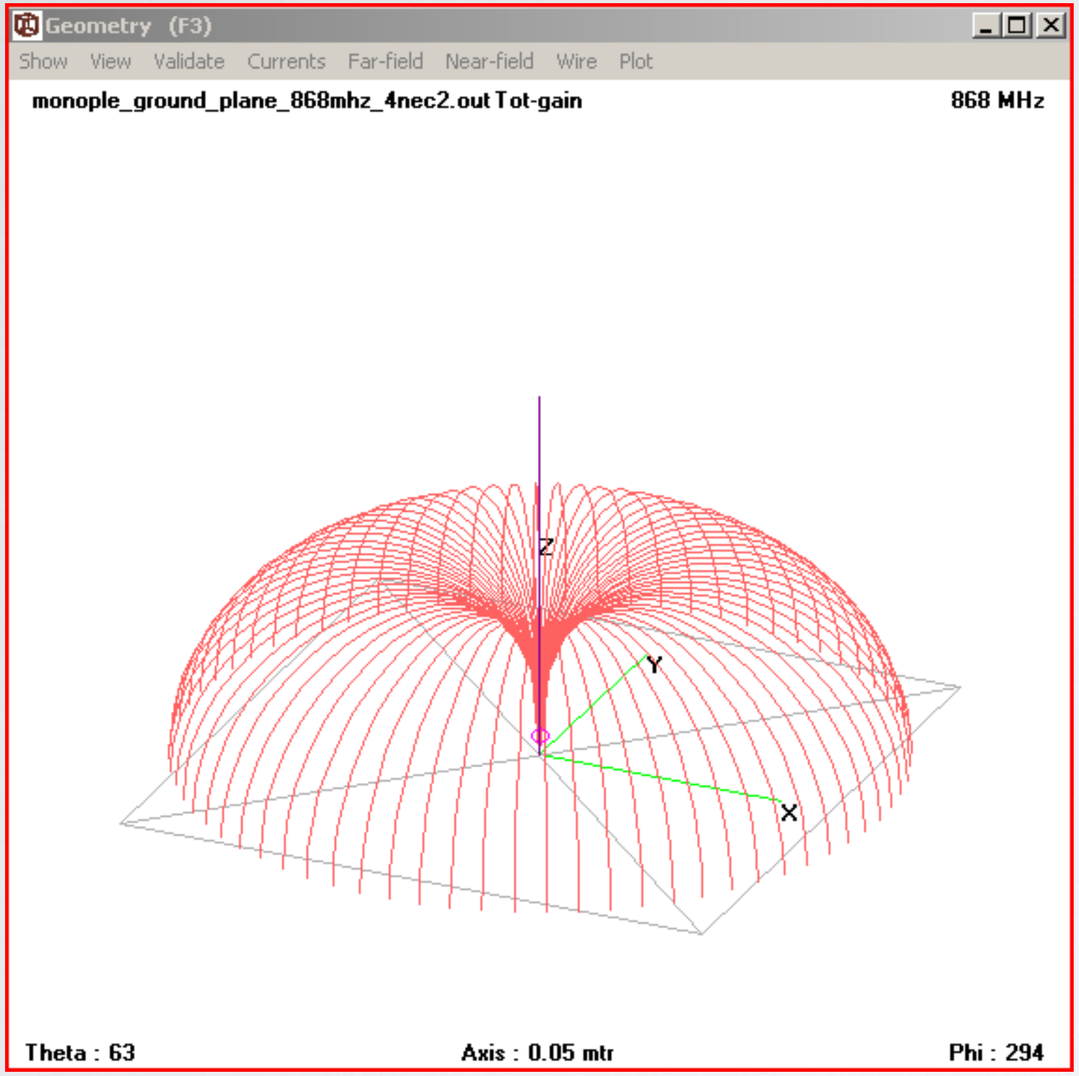
MONOPOLE RADIATION PATTERN

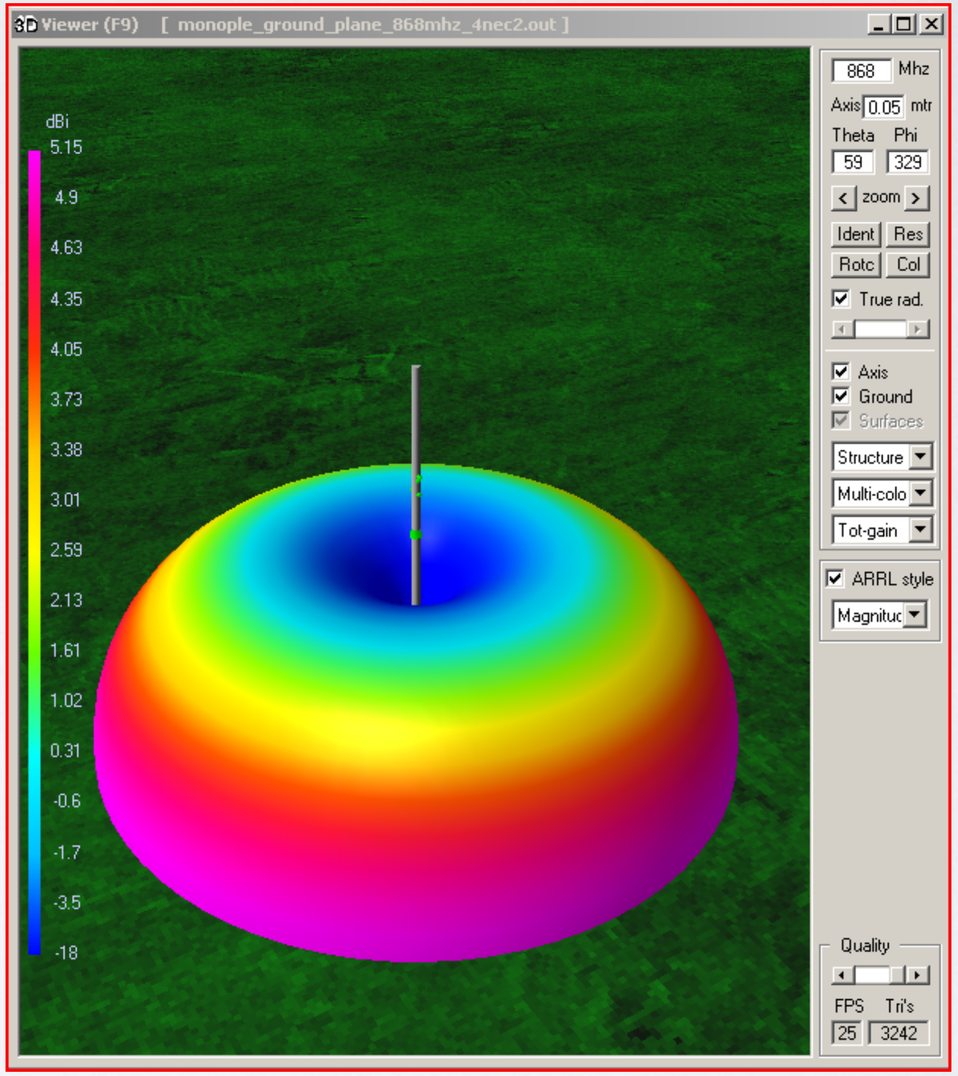




¼λ monopole antenna over perfect ground.

MONOPOLE RADIATION PATTERN



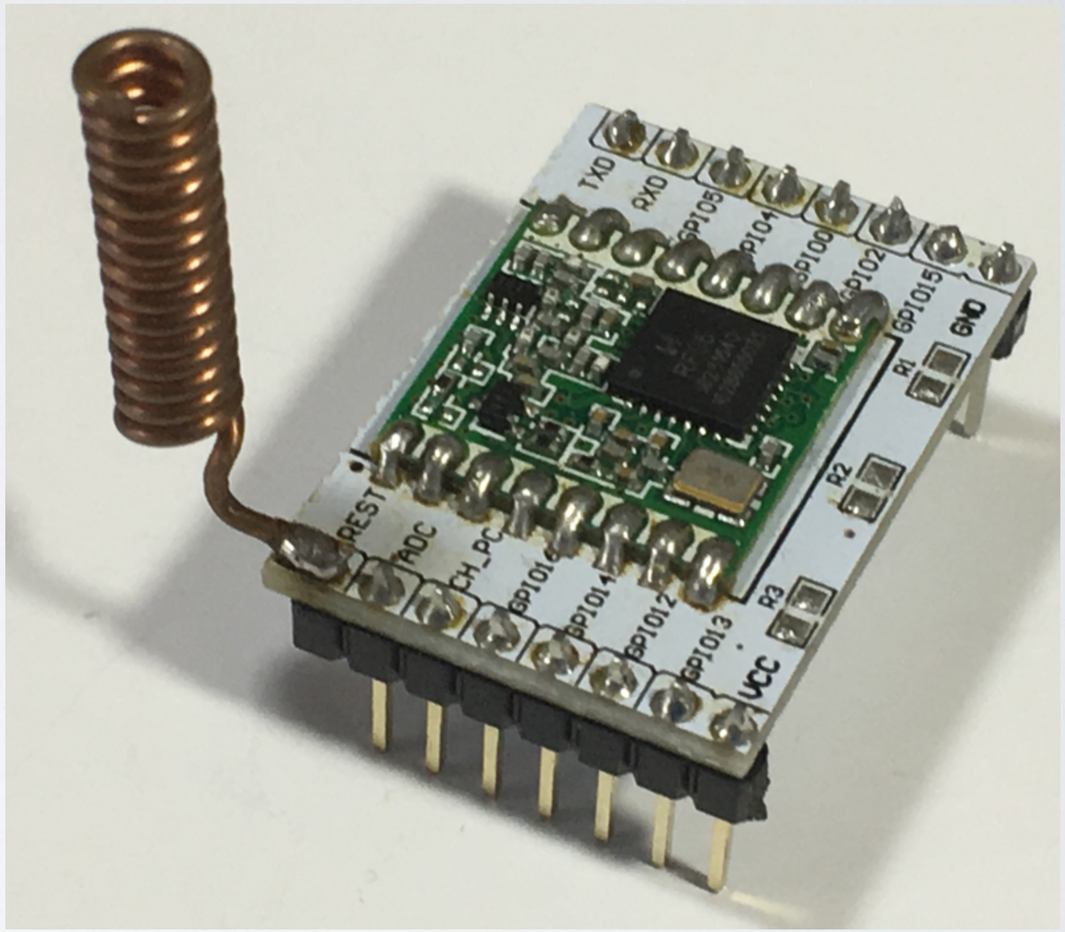


¼λ monopole antenna over perfect ground.

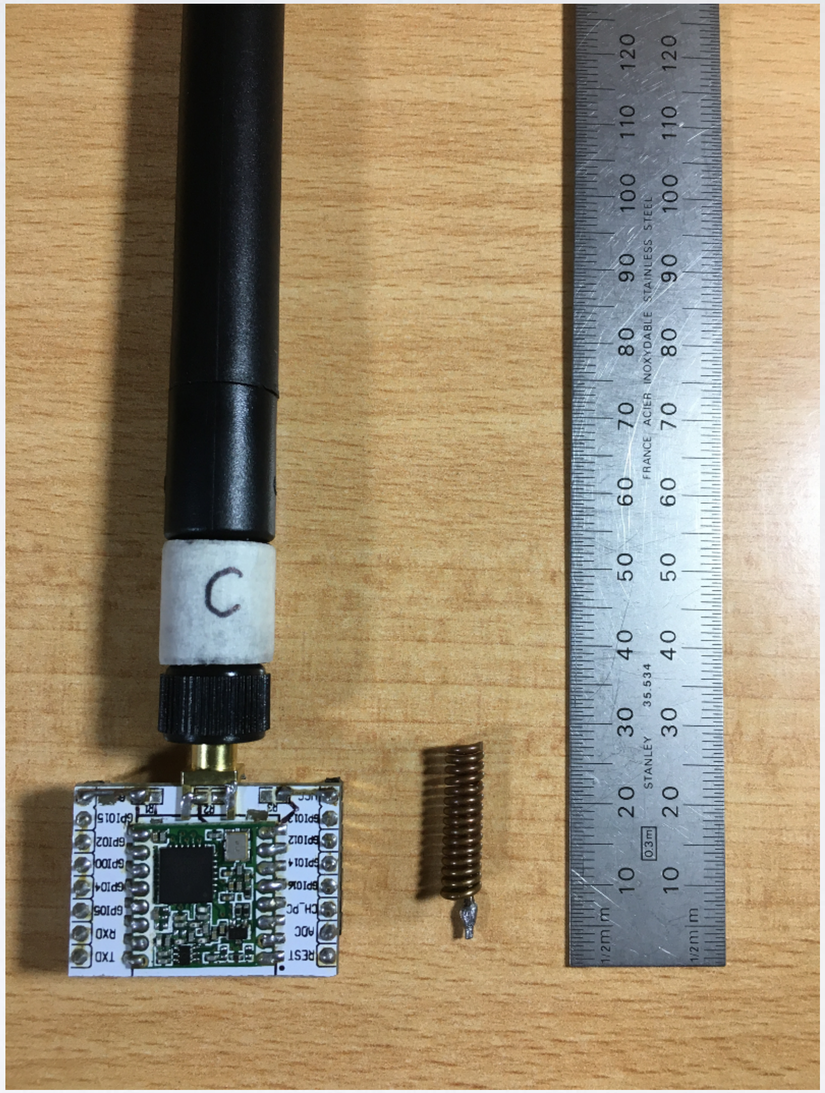
ORIGINAL NORMAL MODE HELICAL ANTENNA

- I actually created this normal mode helical antenna: https://youtu.be/5d2GJOVMWSs

- But I always wondered what is the VSWR of this antenna. The module itself has a negligible ground plane surface (see tutorial 42).

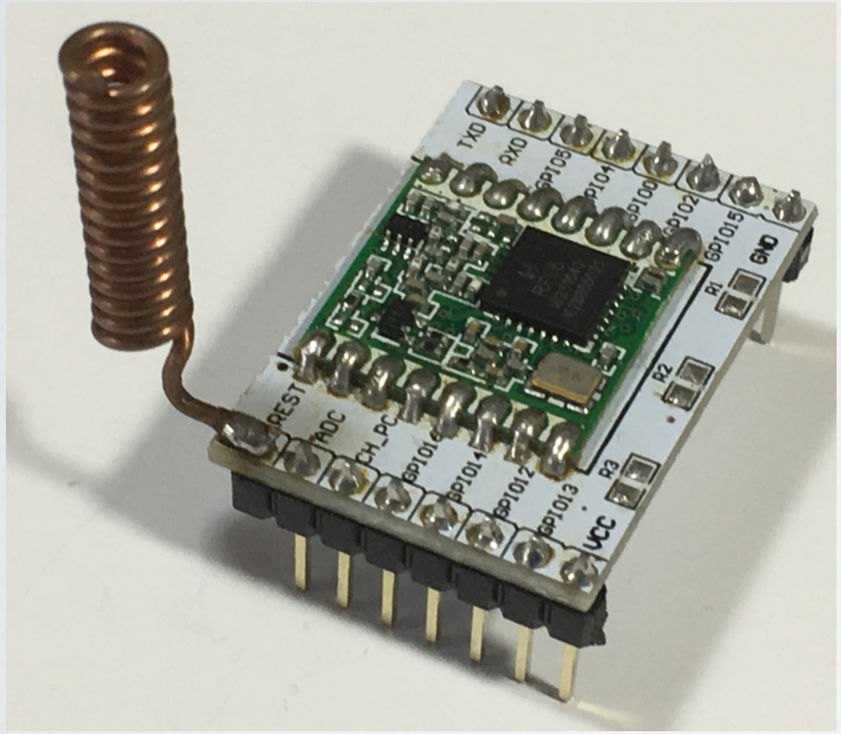


ORIGINAL NORMAL MODE HELICAL ANTENNA

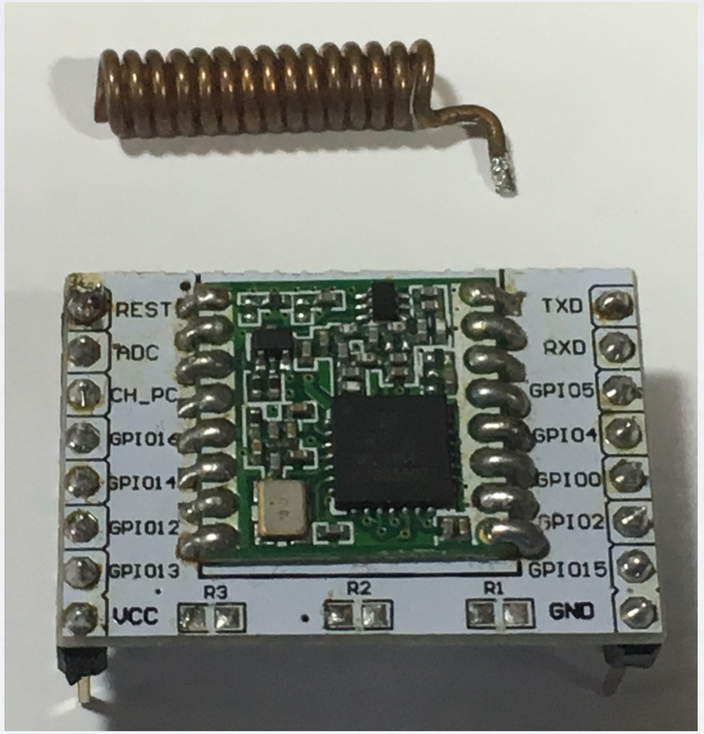


The size of the helical antenna compared to the end node and sleeve dipole antenna.

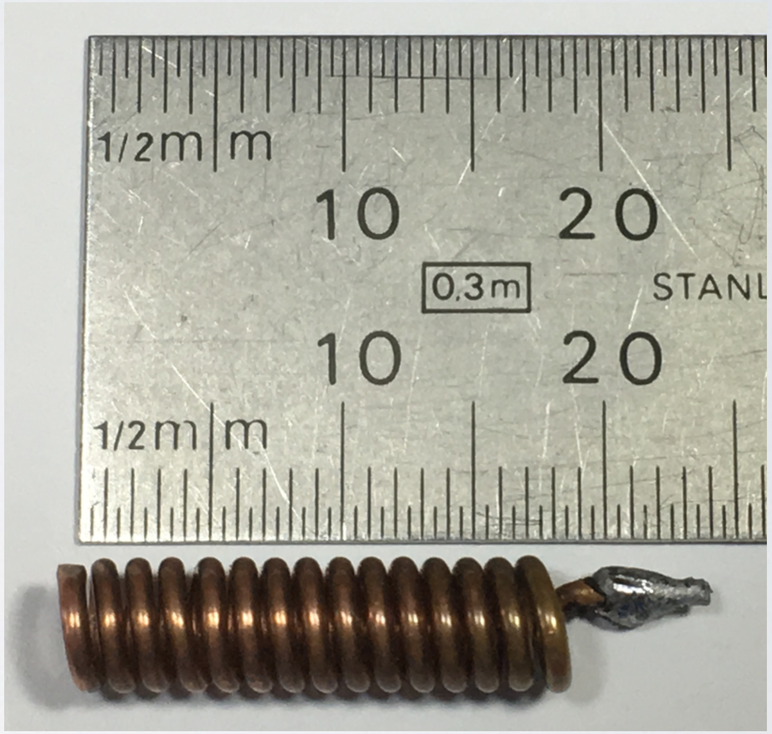
ORIGINAL NORMAL MODE HELICAL ANTENNA



Remove helical antenna



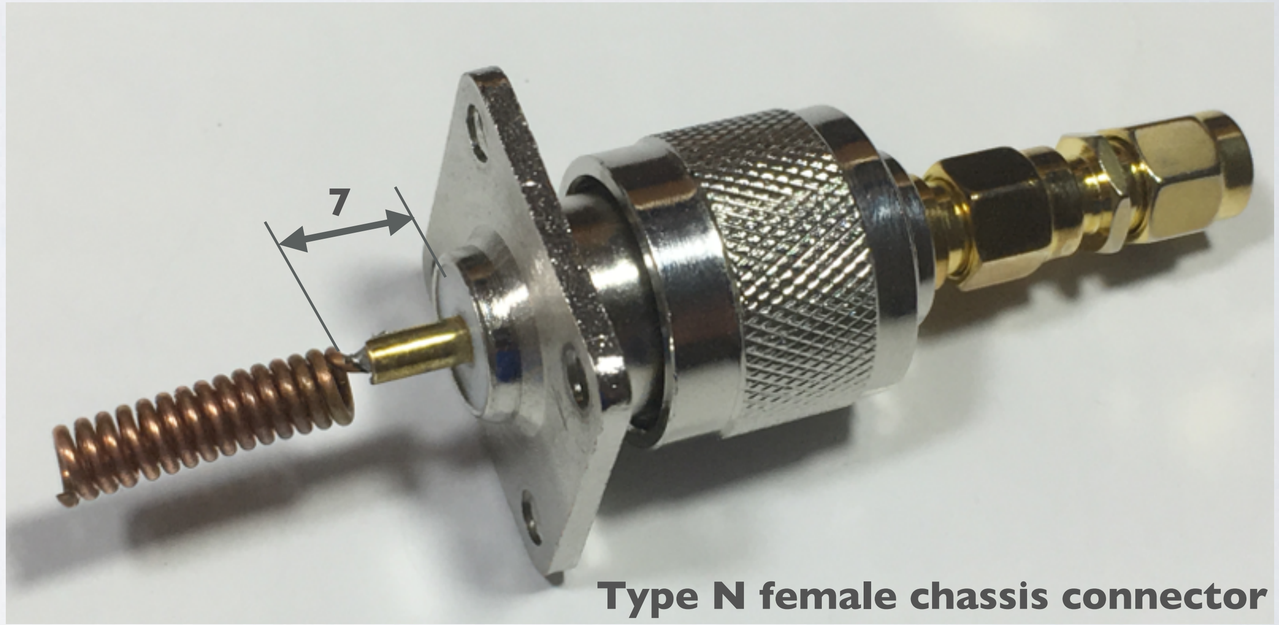
Shorten the solder length



How to create a copper 868MHz coil antenna
https://youtu.be/5d2GJOVMWSs

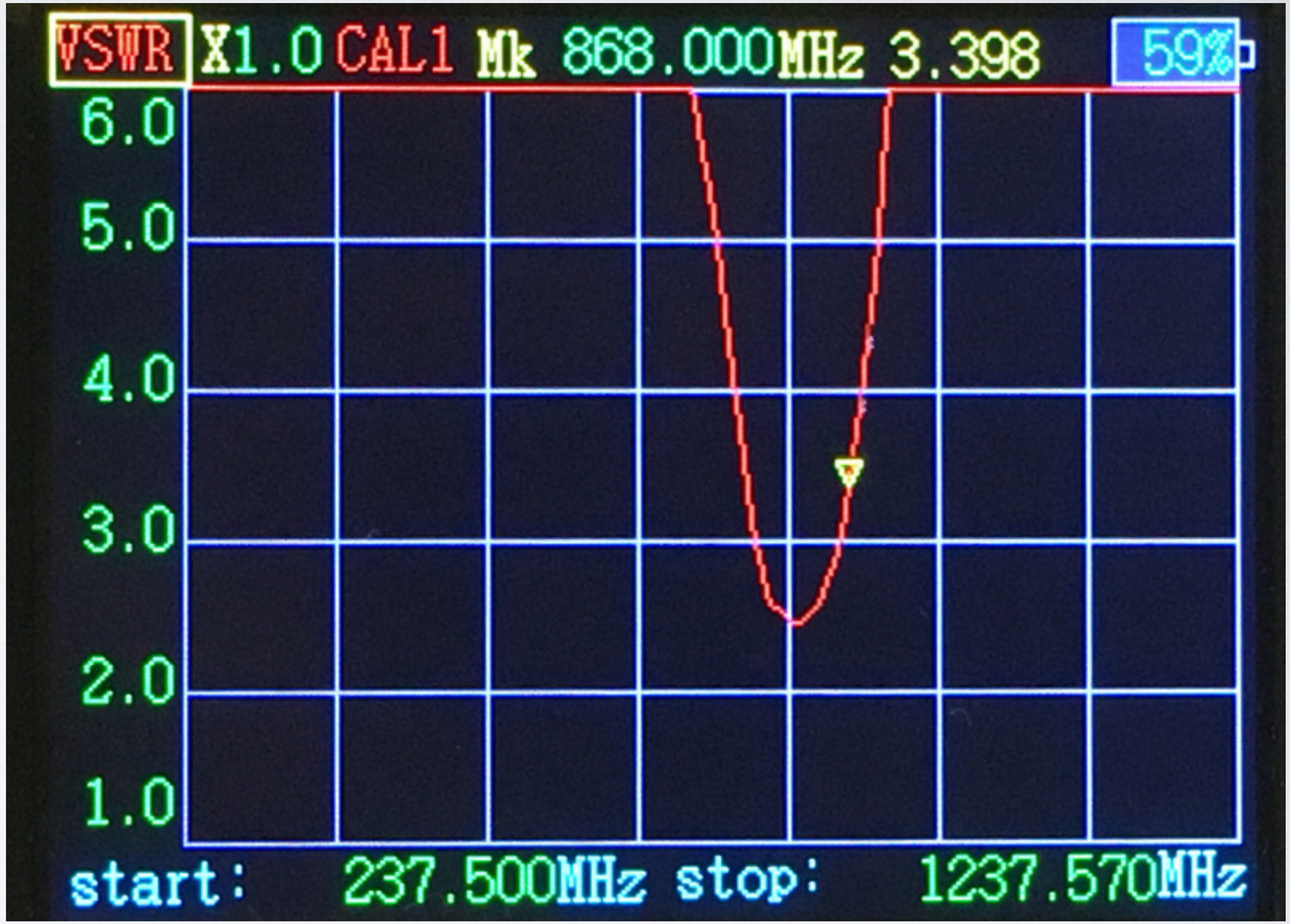
ORIGINAL HELICAL ANTENNA DESIGN

- Unfortunately the length is 7mm instead of 4 mm.
- And the spaces between the coils (S) are irregular and not exactly 1.2 mm.



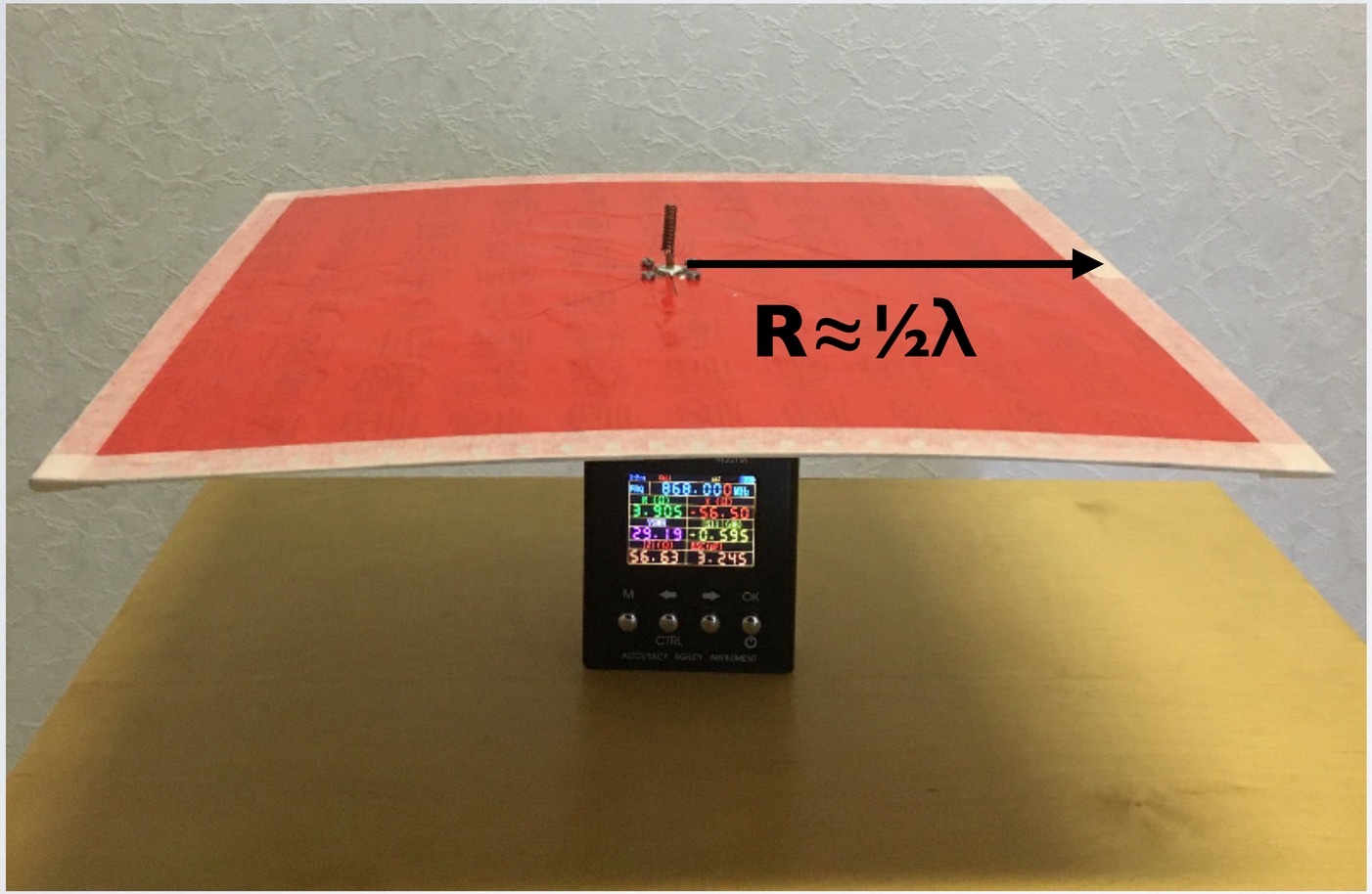
Type N female chassis connector

ORIGINAL HELICAL ANTENNA DESIGN



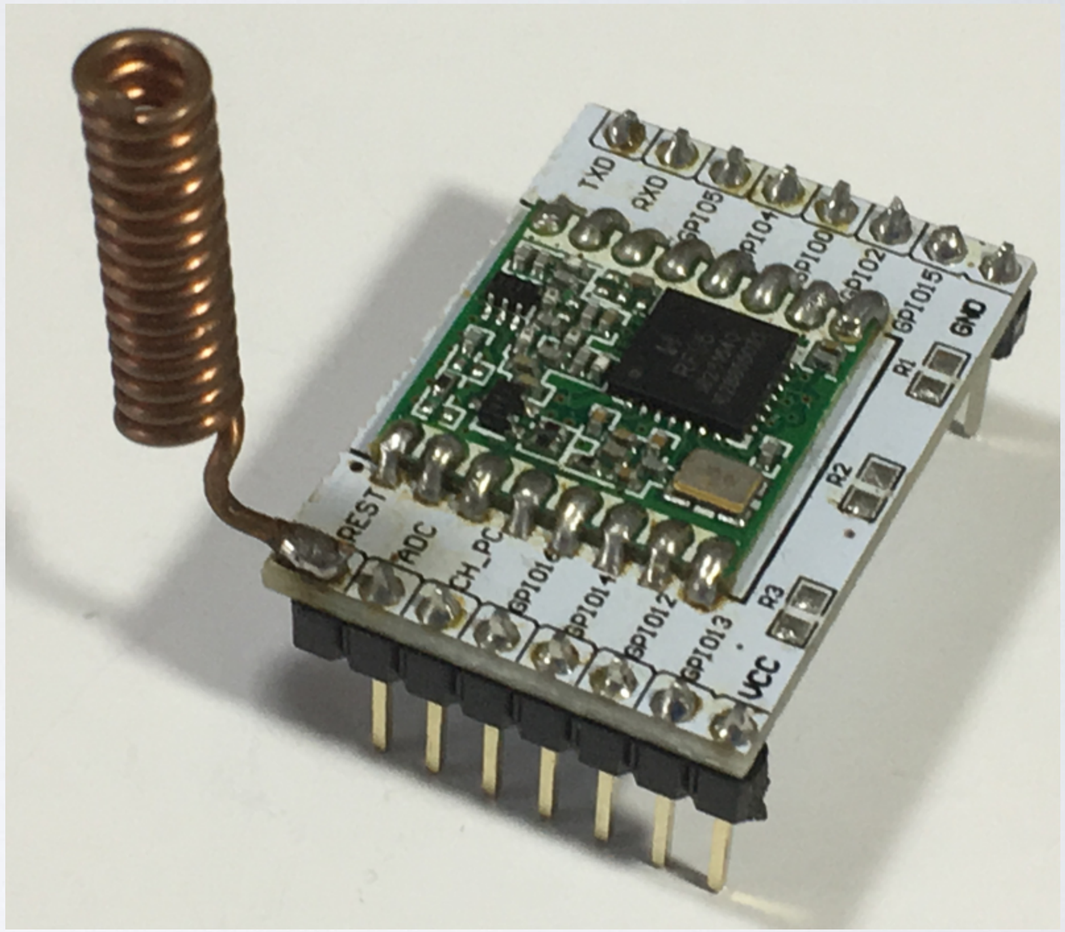
ORIGINAL HELICAL ANTENNA DESIGN

ORIGINAL HELICAL ANTENNA DESIGN



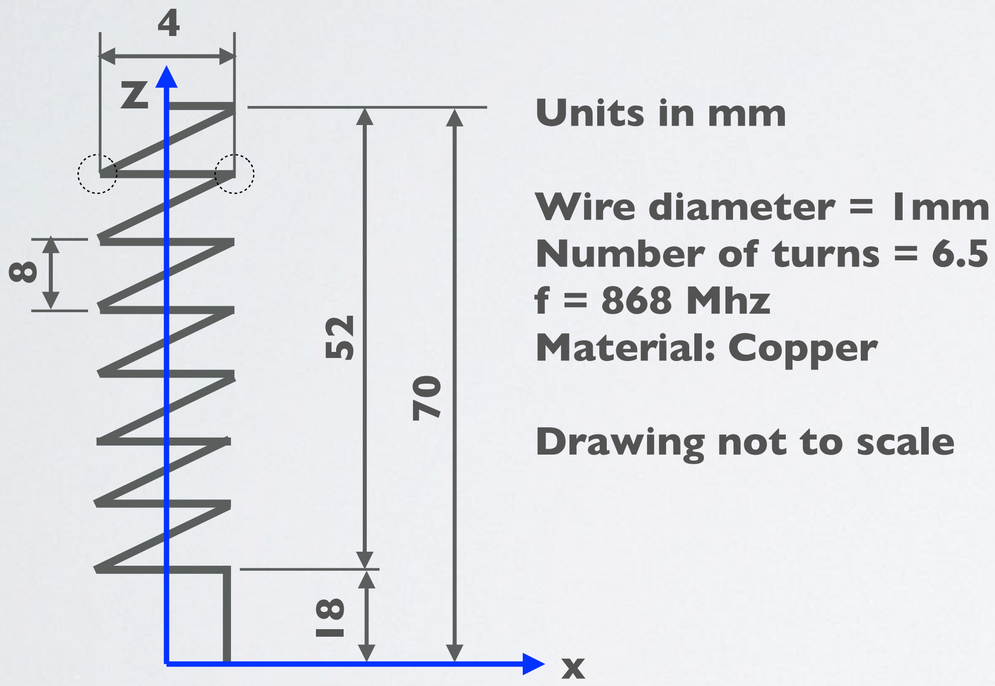
ORIGINAL HELICAL ANTENNA DESIGN

- In the previous slides you will notice the VSWR is greater than 2.
- I could not verify if this normal mode helical antenna is a valid design. I have spend many hours but I have given up, sorry…
- I decided to create my own self designed normal mode helical antenna.



MY NORMAL MODE HELICAL ANTENNA

- The 4NEC2 card deck:
  https://www.mobilefish.com/download/lora/normal_mode_helical_868mhz_4nec2.nec.txt

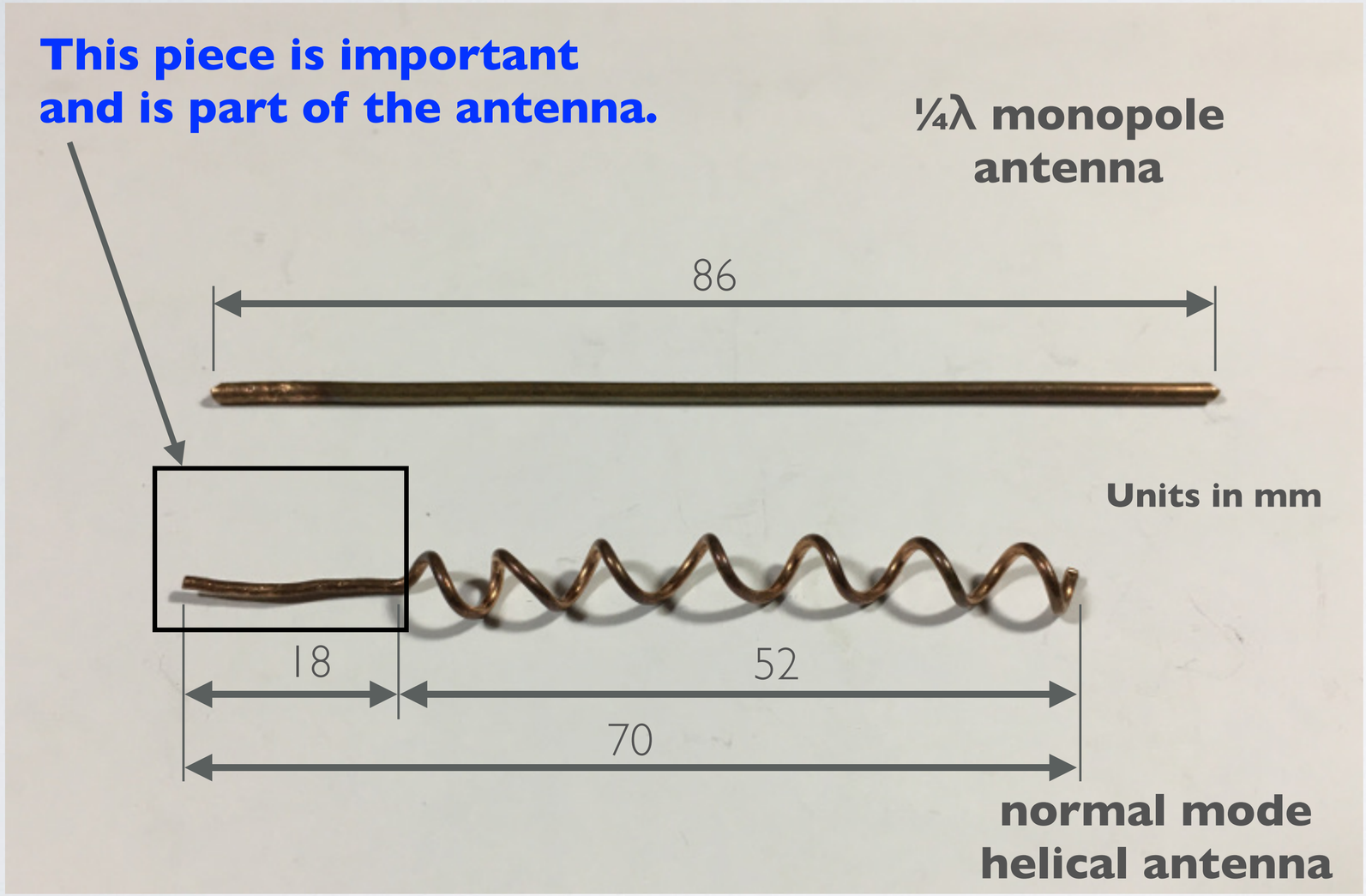


Units in mm

Wire diameter = 1mm
Number of turns = 6.5
f = 868 Mhz
Material: Copper

Drawing not to scale

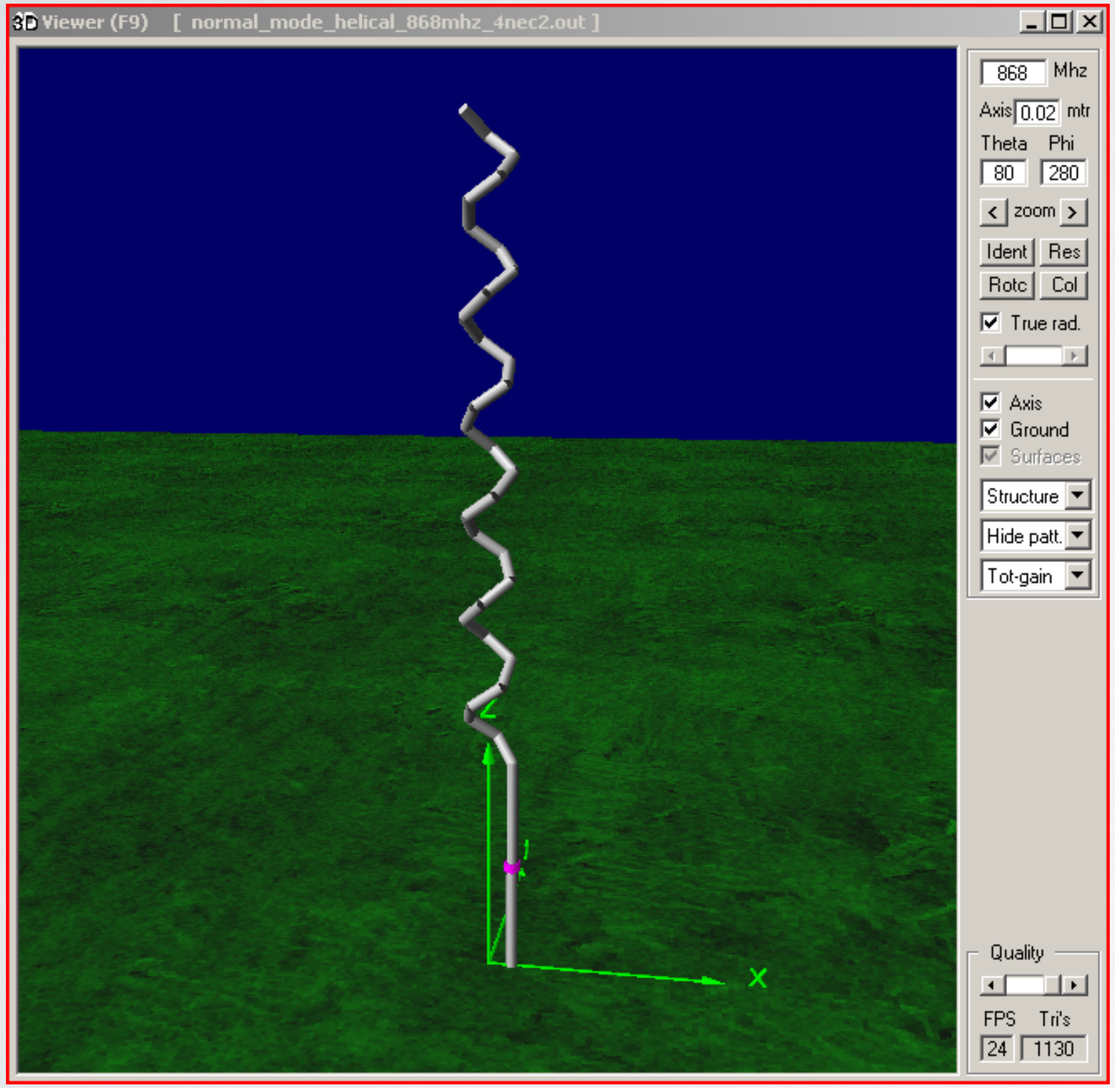
MY NORMAL MODE HELICAL ANTENNA



The normal mode helical antenna is smaller than the ¼λ monopole antenna.

Note:
The length of this normal mode helical antenna can be made smaller.

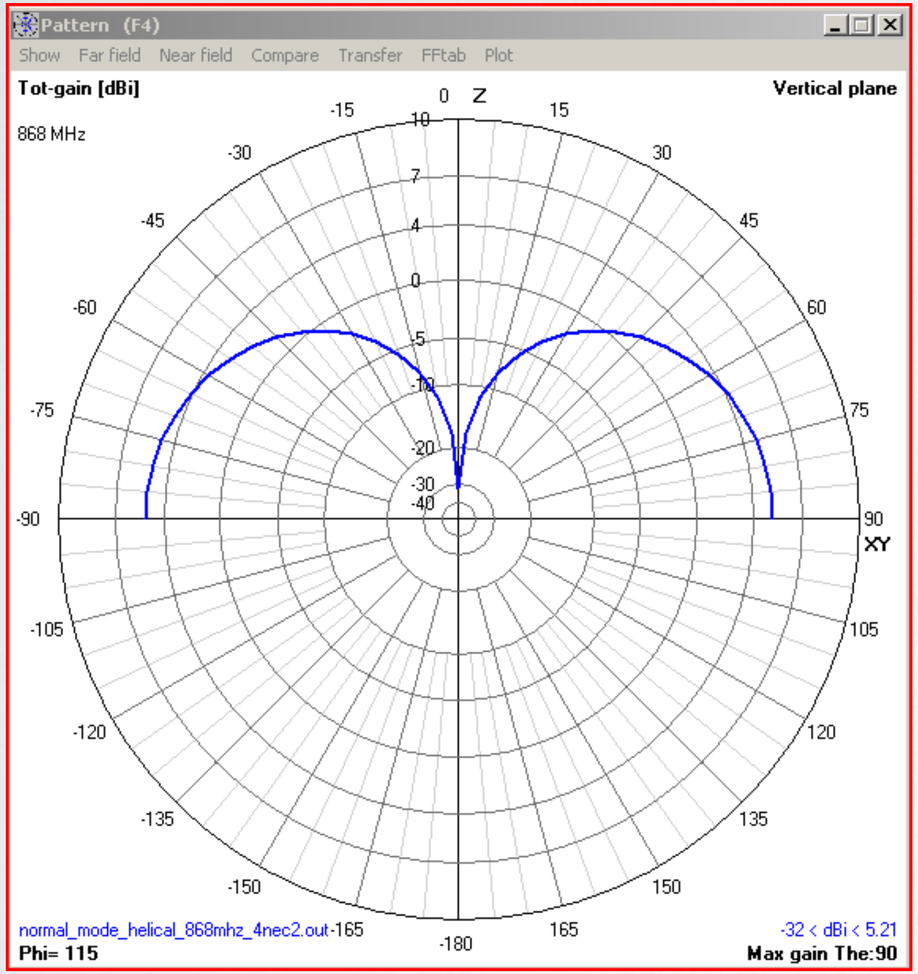
MY NORMAL MODE HELICAL ANTENNA

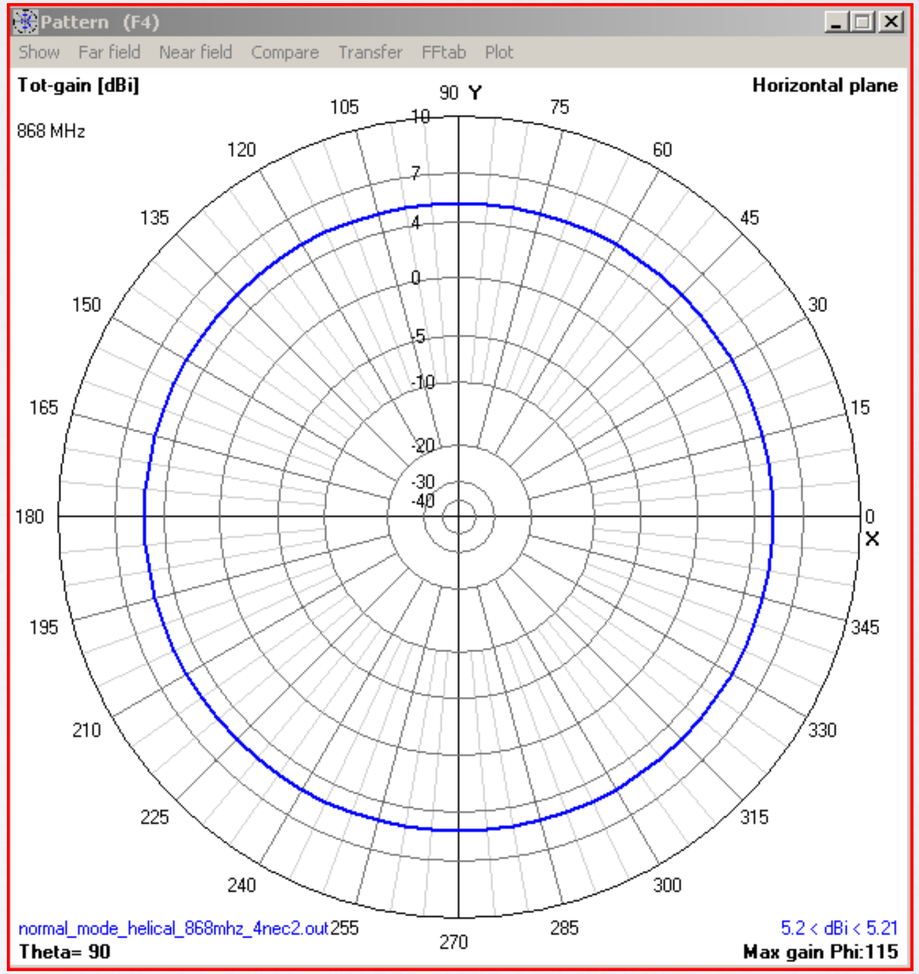


Created in 4NEC2

MY NORMAL MODE HELICAL ANTENNA

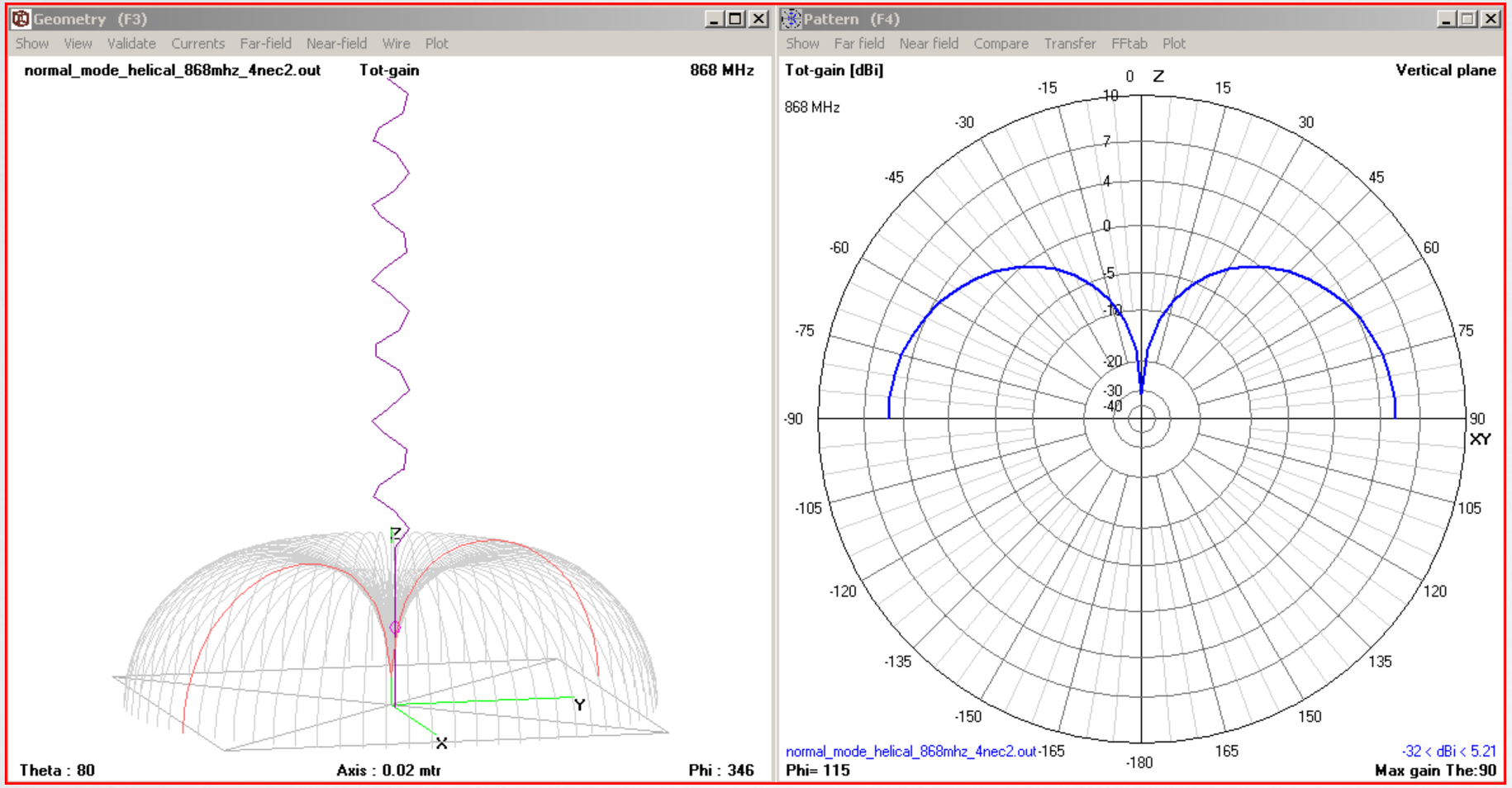
- Ground: Perfect ground (= perfectly conducting ground)



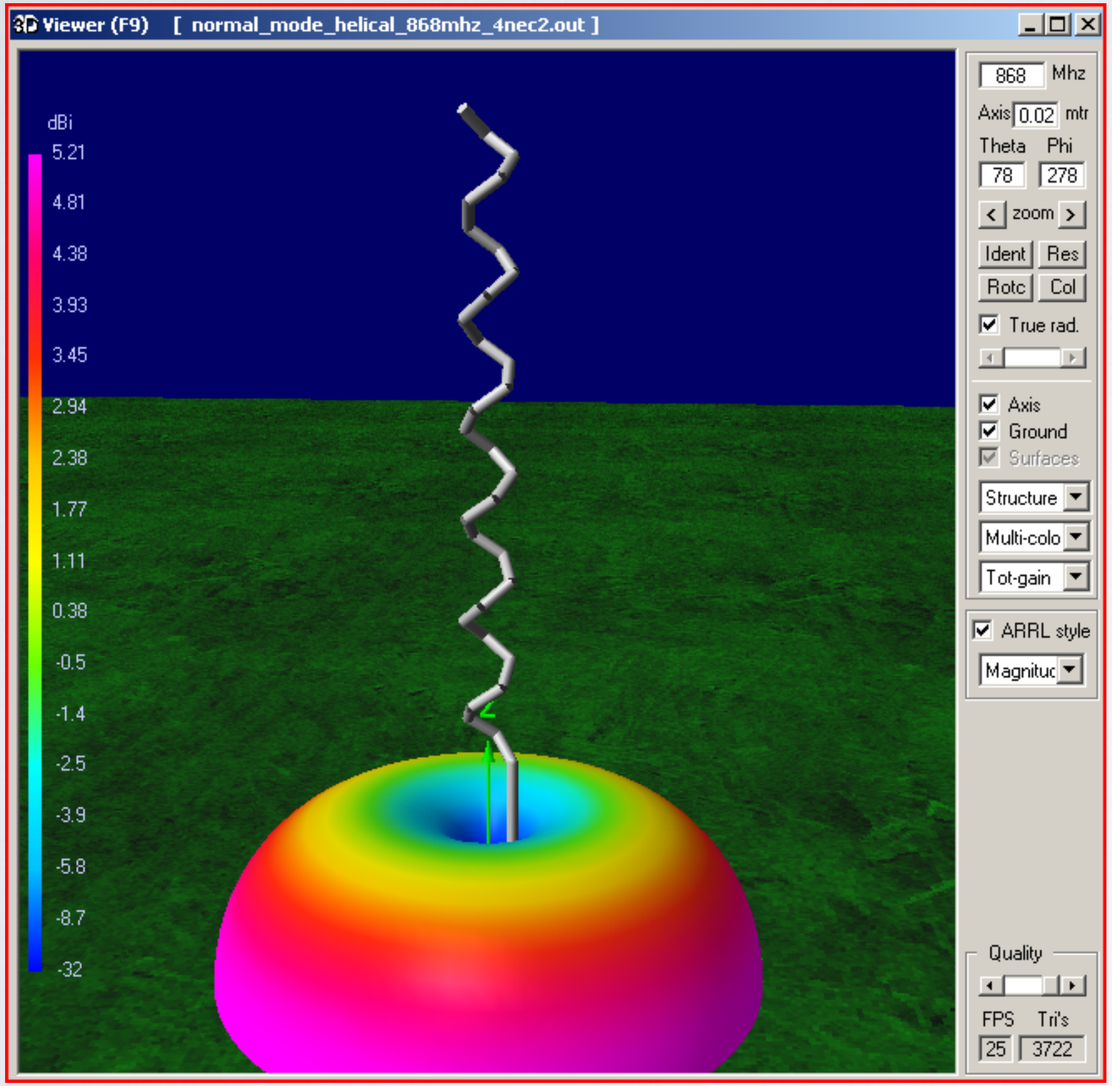


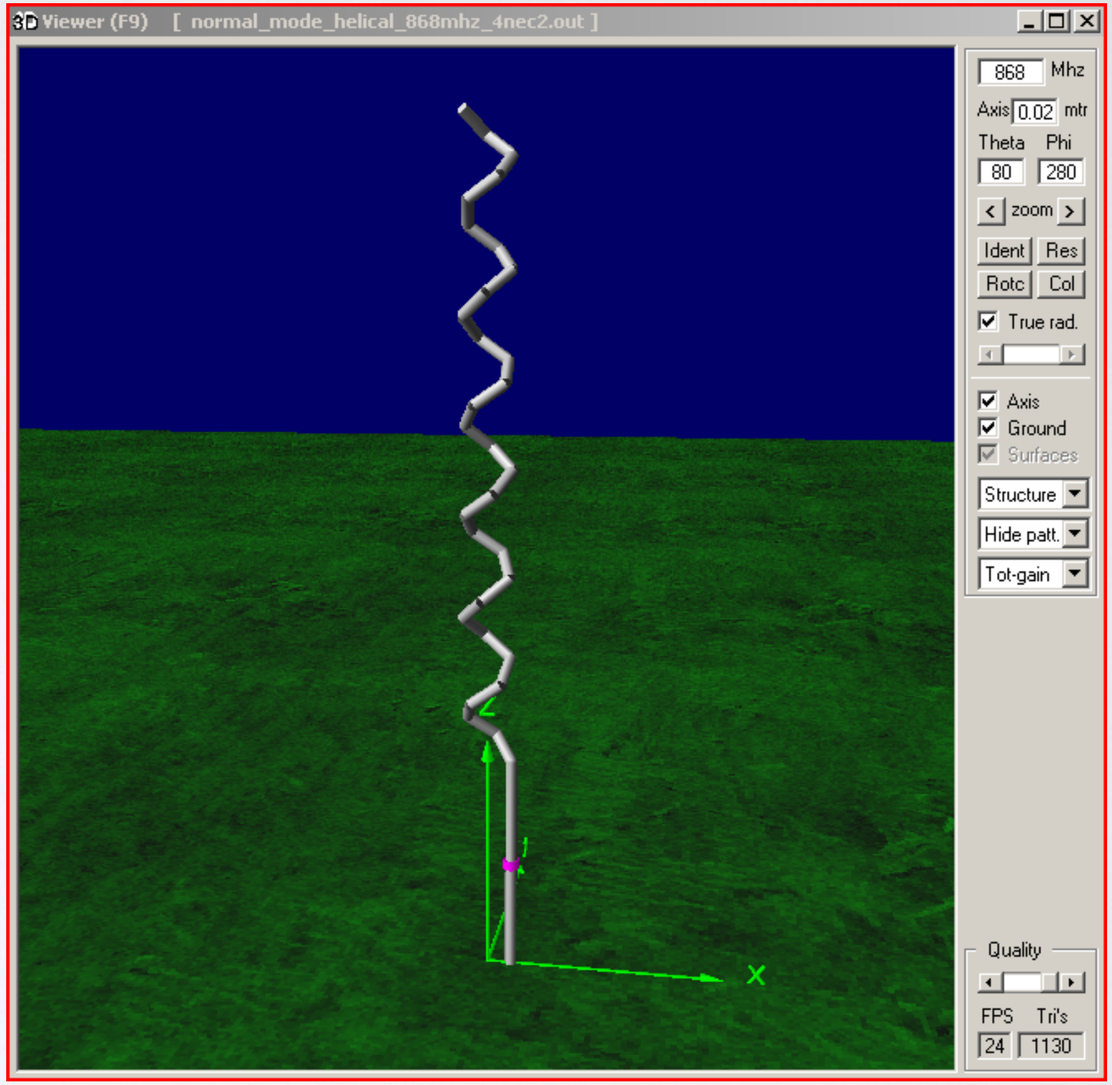
MY NORMAL MODE HELICAL ANTENNA

- Ground: Perfect ground (= perfectly conducting ground)

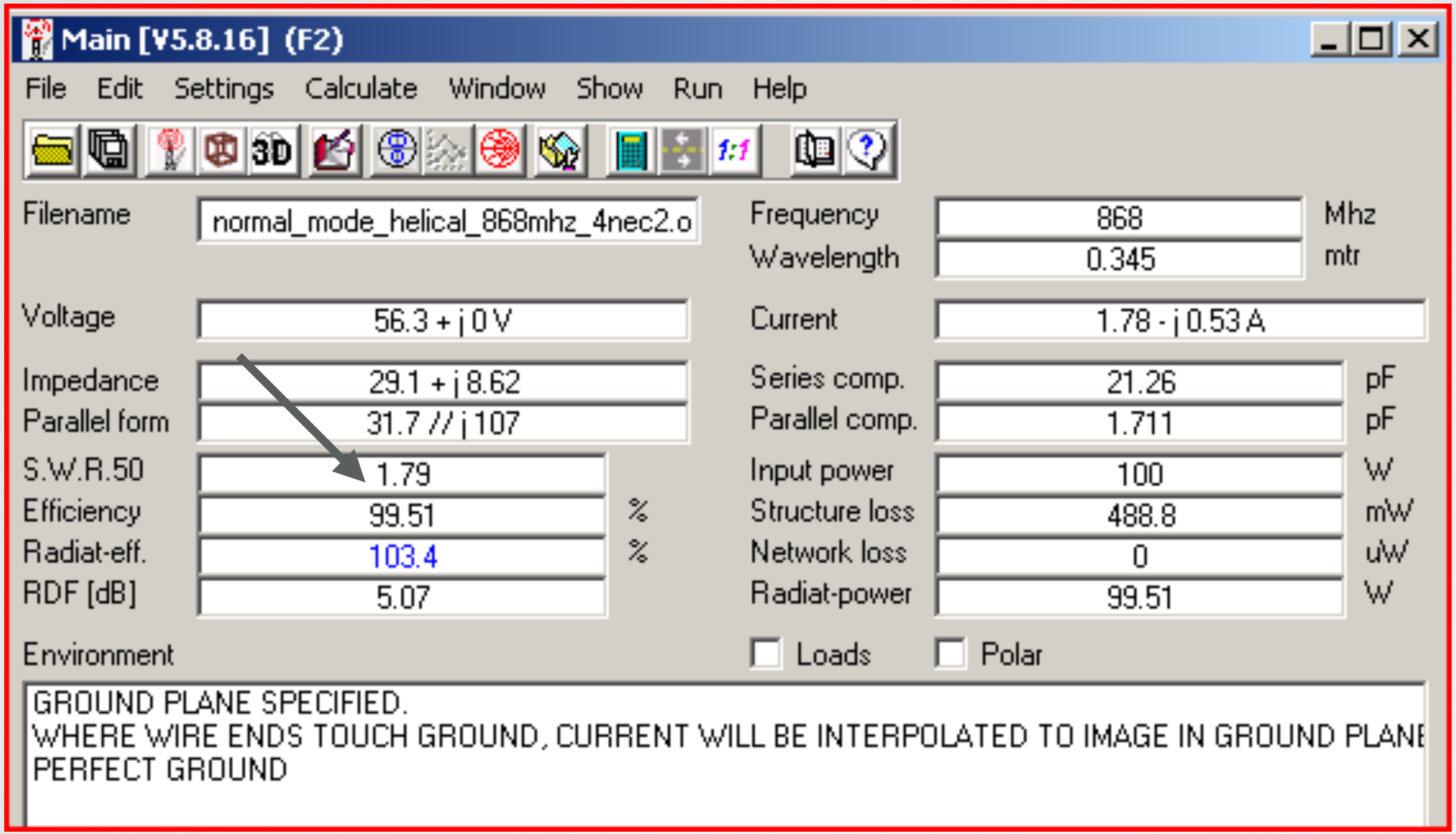


MY NORMAL MODE HELICAL ANTENNA





MY NORMAL MODE HELICAL ANTENNA



VSWR=1.79

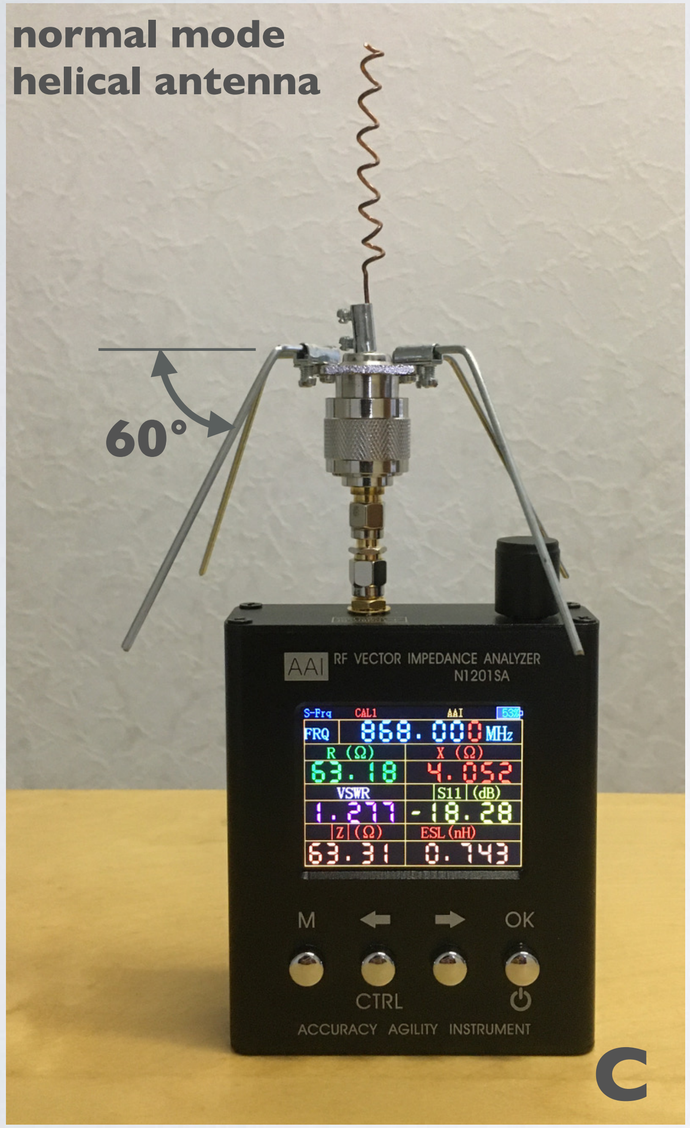
MY NORMAL MODE HELICAL ANTENNA

VSWR ≈ 4.8
Z ≈ 20Ω
S11 ≈ -4 dB

No ground plane

VSWR ≈ 5.5
Z ≈ 20Ω
S11 ≈ -3 dB

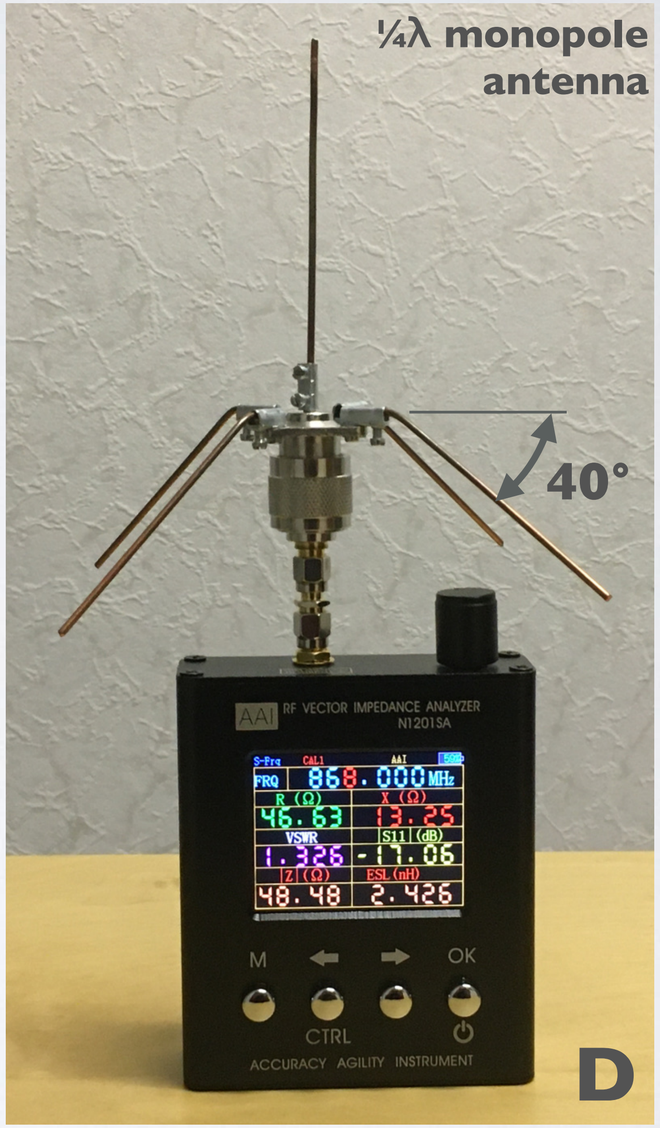
MY NORMAL MODE HELICAL ANTENNA



VSWR ≈ 1.3
Z ≈ 63Ω
S11 ≈ -18 dB
Radial angle = 60°

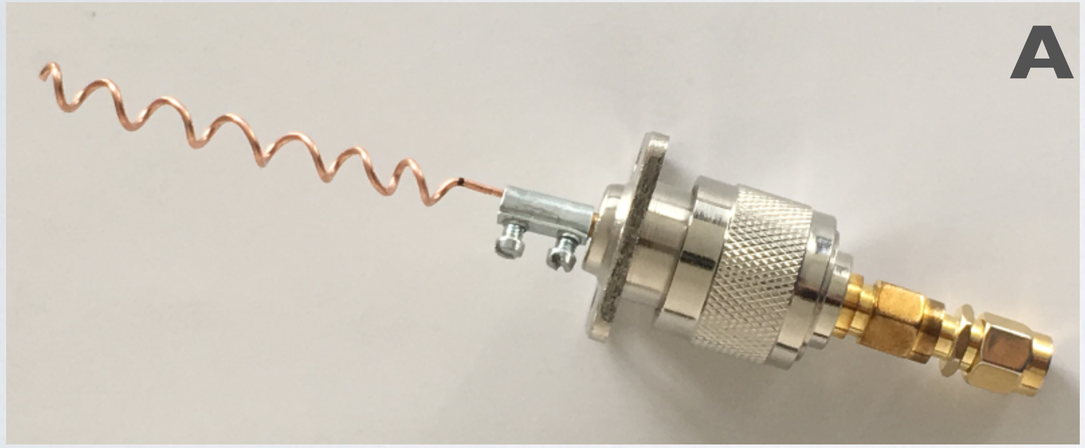
with ground plane (radials)

VSWR ≈ 1.3
Z ≈ 48Ω
S11 ≈ -17 dB
Radial angle = 40°



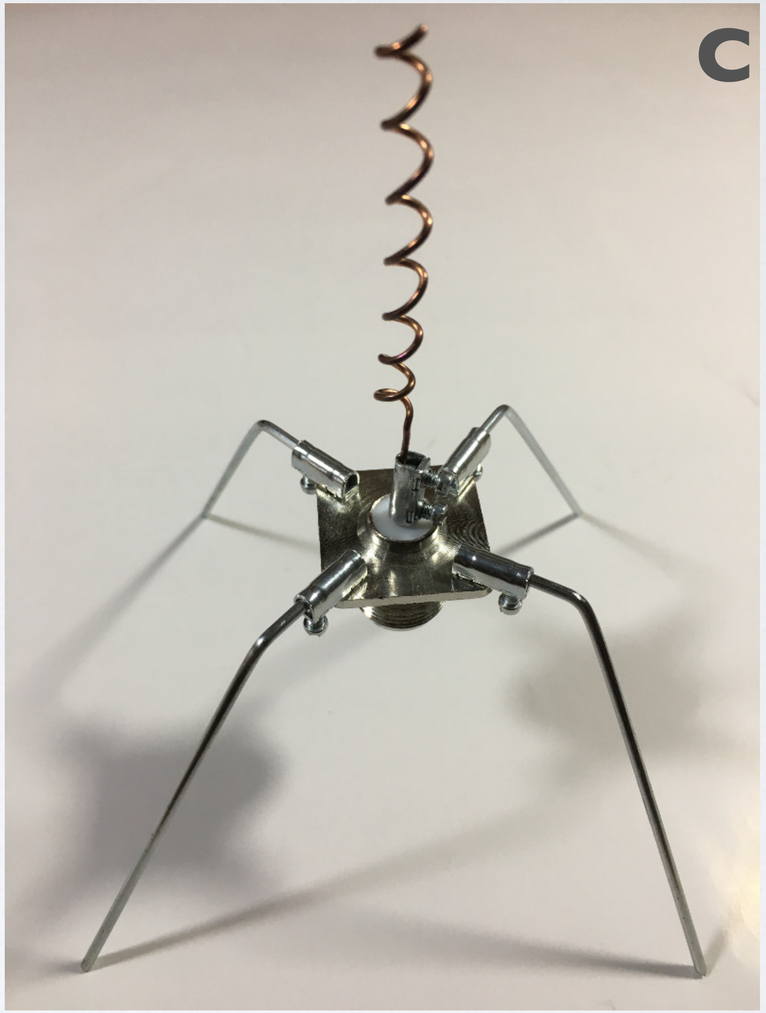
MY NORMAL MODE HELICAL ANTENNA

no ground plane



VSWR ≈ 4.8
Z ≈ 20Ω
S11 ≈ -4 dB

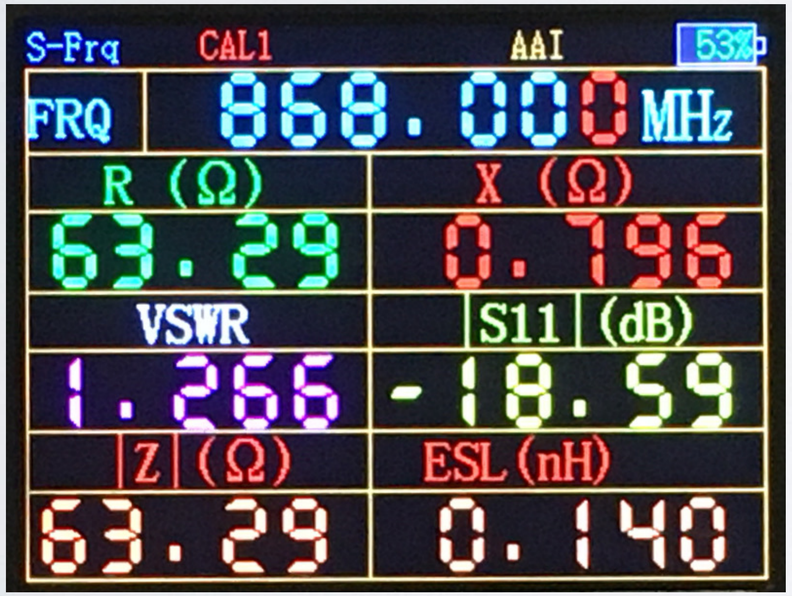
with ground plane

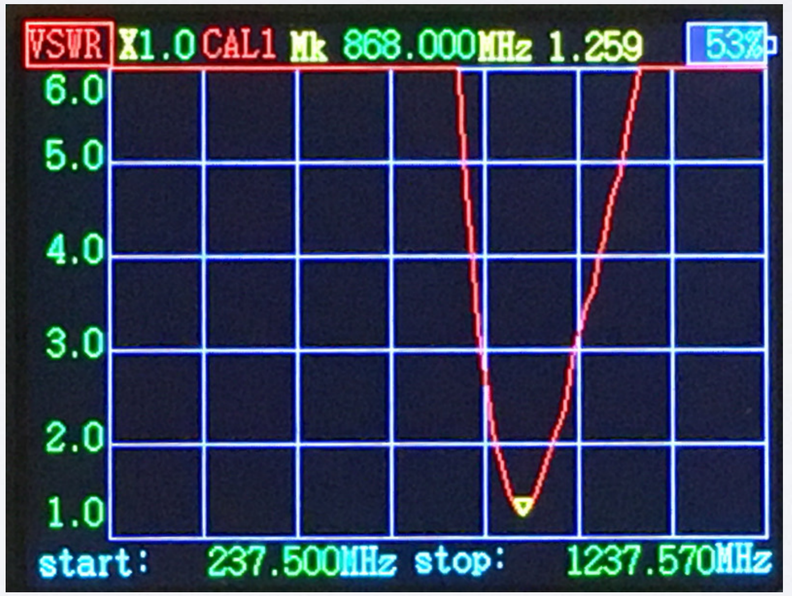


VSWR ≈ 1.3
Z ≈ 63Ω
S11 ≈ -18 dB

MEASURED ANTENNA PARAMETERS

- My normal mode helical antenna with ground plane (photo C):
  VSWR ≈ 1.3 ⟵ Good. It is < 2
  Z ≈ 63Ω ⟵ Good. Should be approx. 50Ω
  S11 ≈ -18 dB





MEASURED ANTENNA PARAMETERS

ANTENNA TEST SETUP

- The normal mode helical antenna performance is compared with a sleeve dipole antenna. More information about sleeve dipole antennas, see tutorial 43.

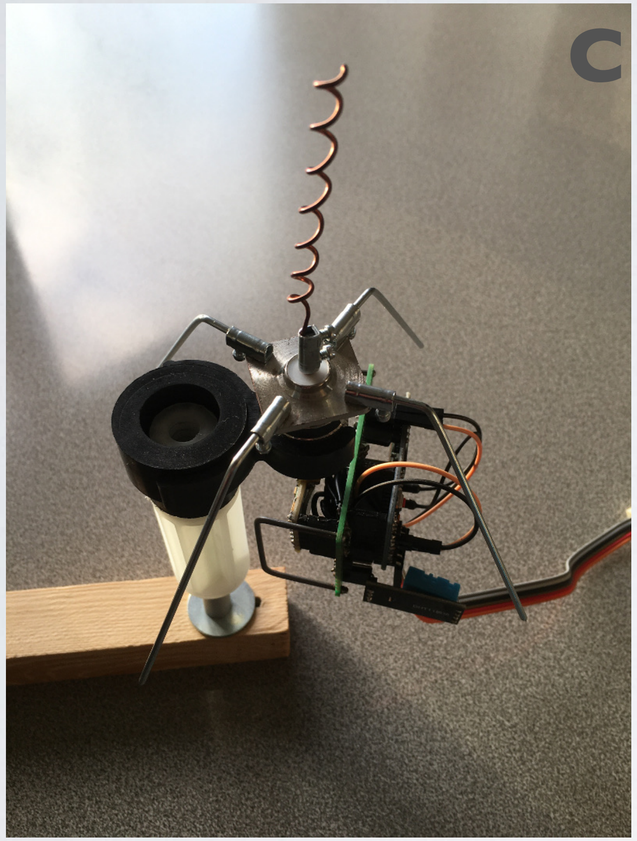
- For this test I am using the end node and antenna C as demonstrated in tutorial 33.

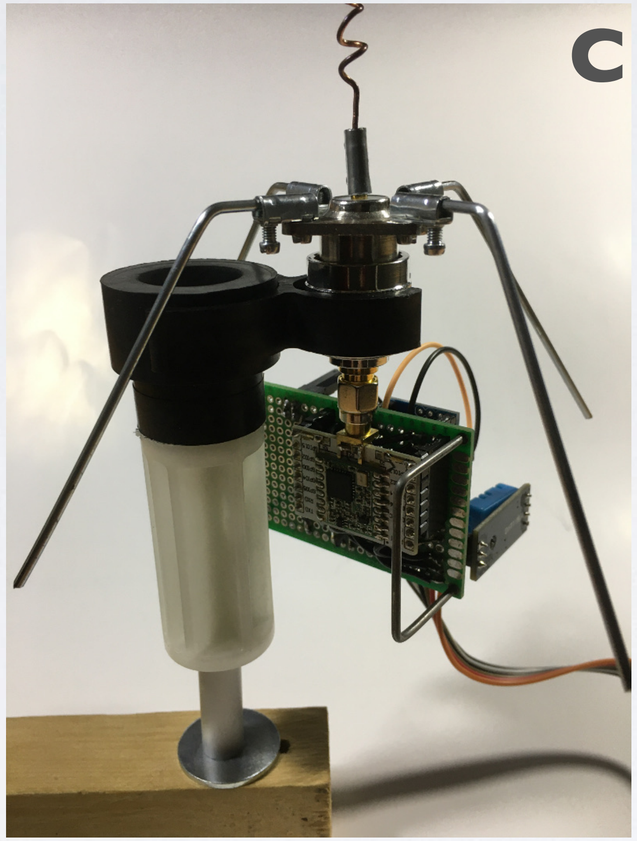
- More information about this end node, see: https://www.mobilefish.com/developer/lorawan/lorawan_quickguide_build_lora_node_rfm95_arduino_pro_mini.html

- The end node uses the MCCI LoRaWAN LMIC Library: https://github.com/mcci-catena/arduino-lmic

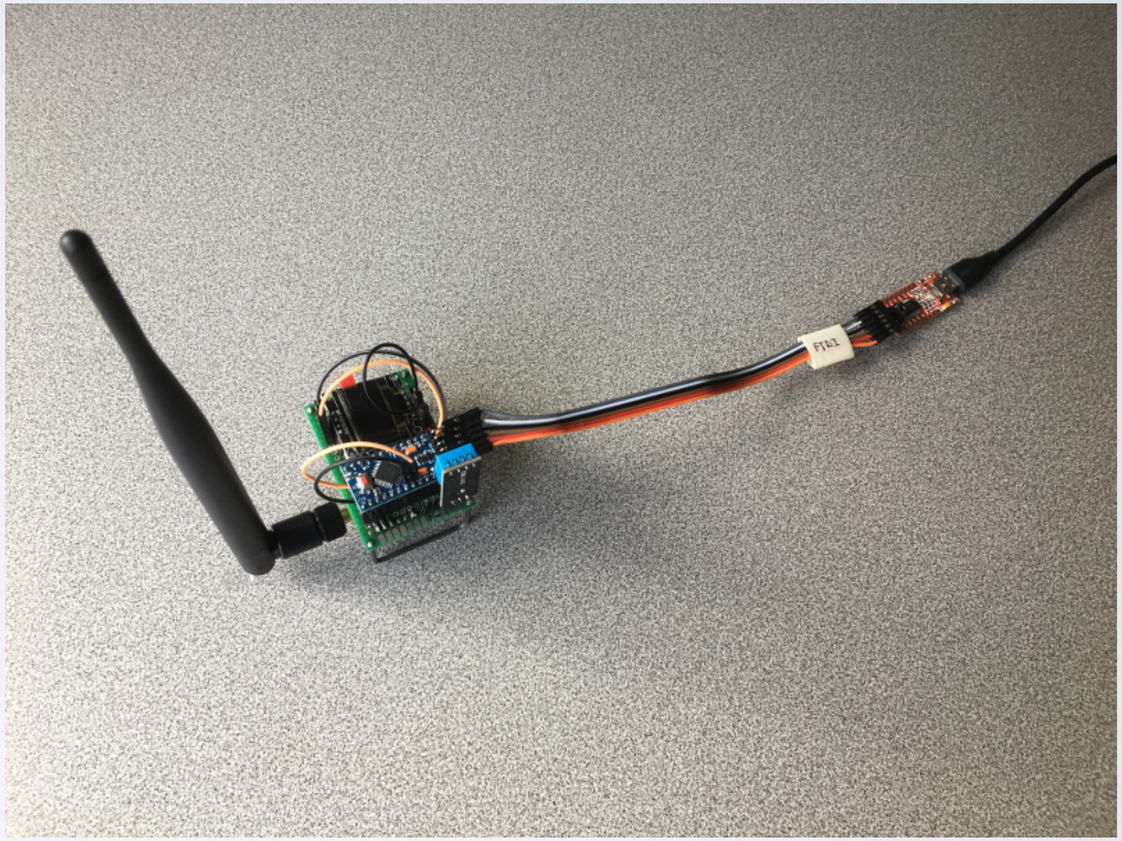
- The end node uses the following sketch: https://www.mobilefish.com/download/lora/ttn-otaa-pro-mini-sensors.ino.txt

ANTENNA TEST SETUP



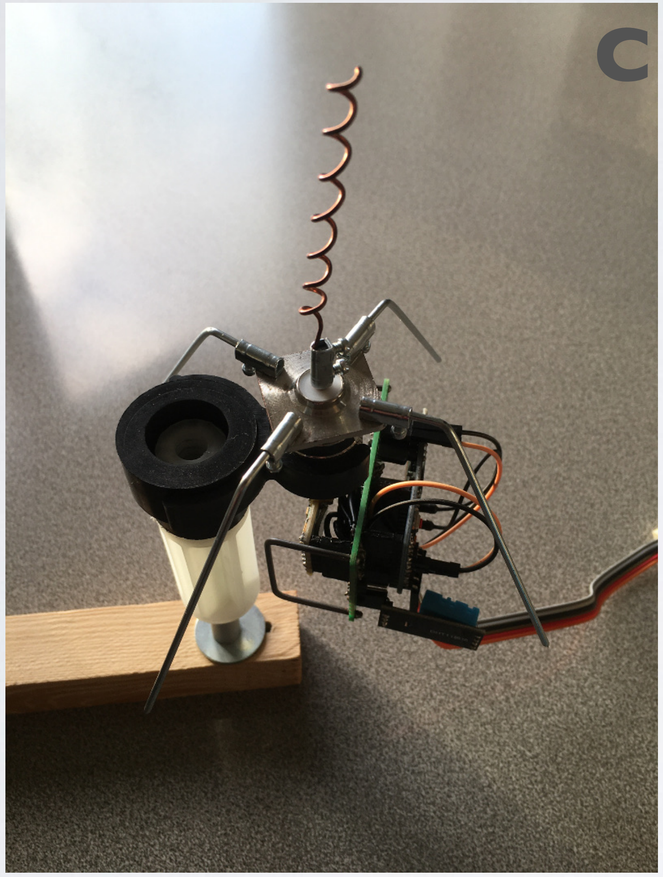


normal mode helical antenna with ground plane + end node

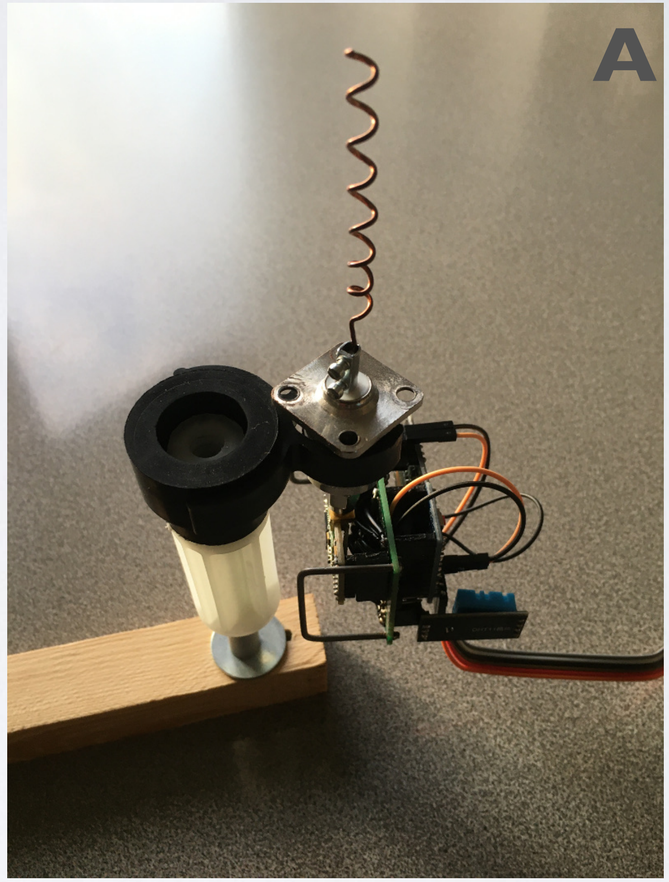


Sleeve dipole + end node

ANTENNA TEST SETUP

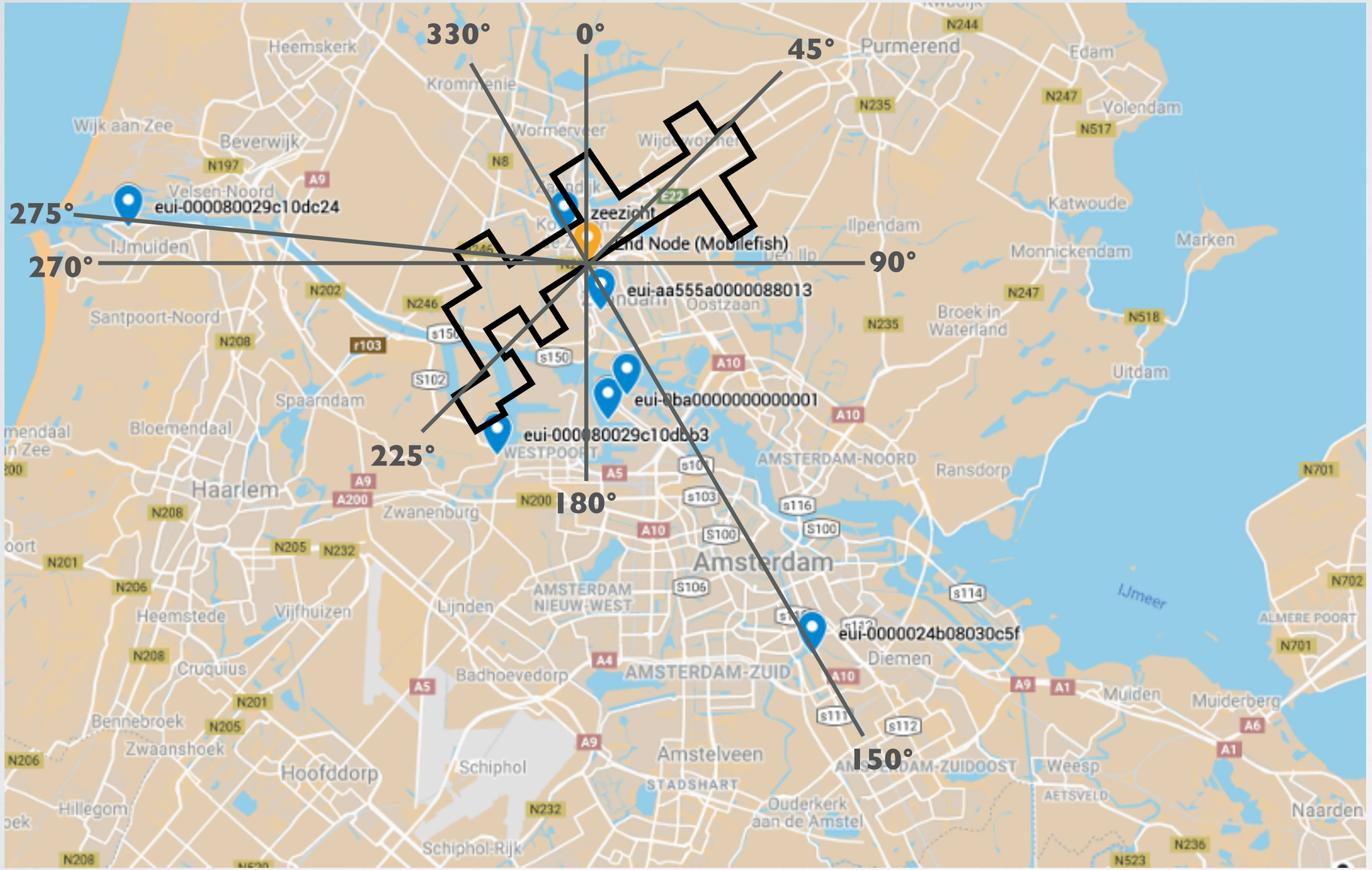


normal mode helical antenna with ground plane + end node



normal mode helical antenna with no ground plane + end node

ANTENNA TEST SETUP



The building circumference.

The end node is placed inside the building in front of a window.

Two end node locations:

Location A, facing East and South. Altitude = ~11m

Location B, facing West and North. Altitude = ~11m

ANTENNA TEST SETUP

- I have NOT modified the end node transmission power when using the different antennas.

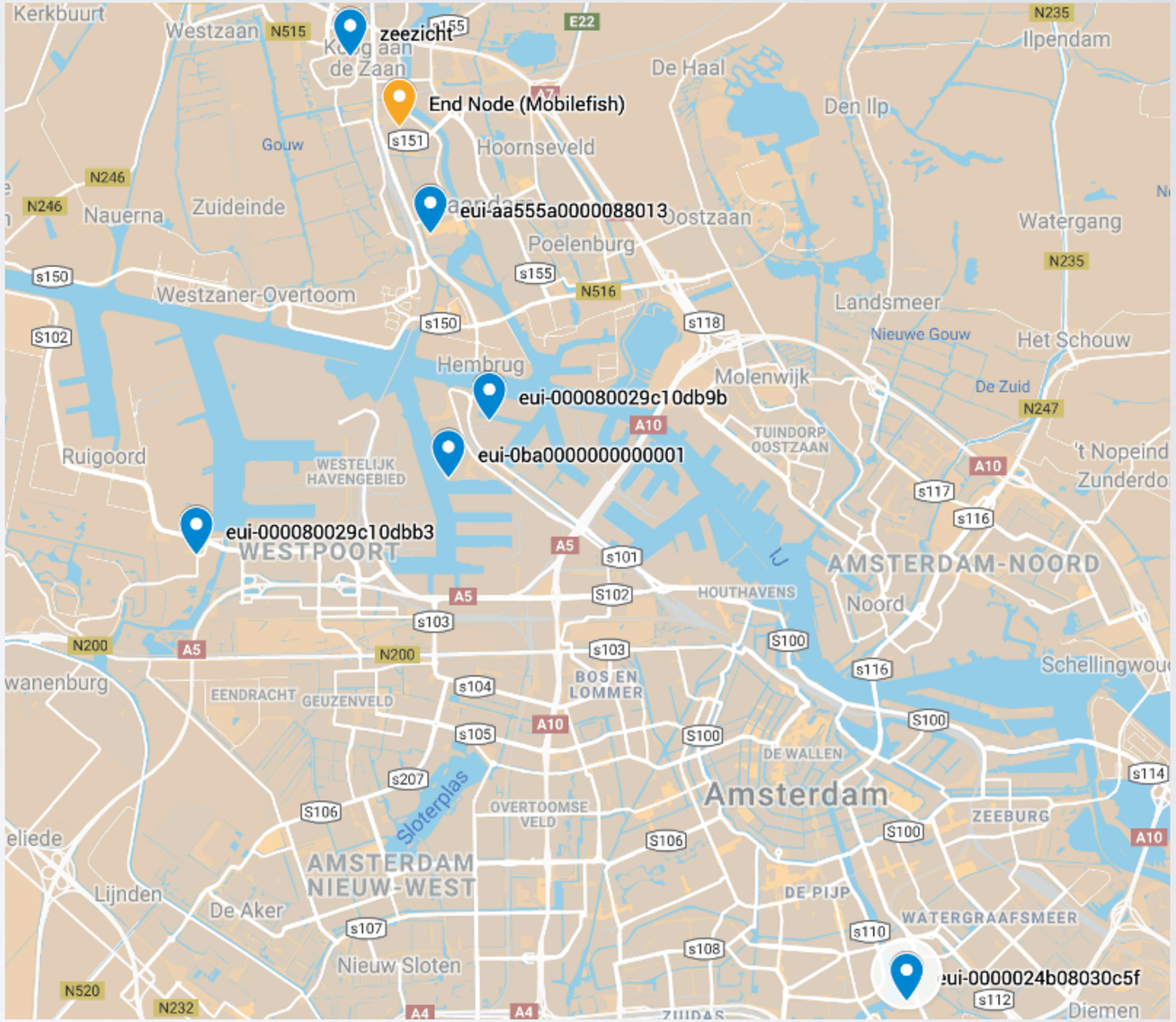
- In my area there are several gateways and I know that these gateways, which are connected to The Things Network, can receive my transmitted data.

- The normal mode helical antenna with ground plane and with no ground plane are attached to the end node at location A and transmits data. I have done the same with the sleeve dipole antenna. In these three cases two messages per minute were transmitted.

- The logged data can be found at: https://www.mobilefish.com/download/lora/normal_mode_helical_ground_plane_test_results.txt

ANTENNA TEST RESULTS

- One or more gateways were able to receive my transmitted sensor data, see: https://drive.google.com/open?id=18SKbHVEIFHU6YjzYpgZL98vuHcmV4OPQ&usp=sharing



ANTENNA TEST RESULTS

- End node tx power = 14 dBm
  Data from: normal_mode_helical_ground_plane_test_results.txt

Gateway	Distance from end device [km]	Altitude [m]	normal mode helical antenna with ground plane Average RSSI [dBm]	Sleeve dipole Average RSSI [dBm]	normal mode helical antenna no ground plane Average RSSI [dBm]
eui-000080029c10dc24	14.7	45	-119.6 *	-	-
eui-7276ff000b031ebb	0.73	38	-88.9	-90.7	-112.7
eui-b827ebfffedcc77d	4.36	7	-80.6	-	-
eui-dca632fffe43df3e	0.458	10	-103.0	-105.7	-
eui-0ba0000000000001	5.02	20	-117.0	-117.3	-

* Only one or few measurements. I will ignore these results.

ANTENNA TEST RESULTS

- If you look at the results you may notice there is no significant difference in the average RSSI values between the normal mode helical antenna with ground plane and the sleeve dipole antenna. If you look at the time it took to transmit 15 messages there is almost no difference.

- When using the normal mode helical antenna with ground plane it took 8.5 minutes to transmit 15 messages.

- When using the sleeve dipole antenna, which is my reference antenna, it also took 8.5 minutes to transmit 15 messages.

- But when using the normal mode helical antenna without ground plane it took 14.5 minutes to transmit 15 messages.

ANTENNA TEST RESULTS

- The Arduino sketch is configured to transmit 2 messages per minute. In a perfect situation it should take 7.5 to 8 minutes to transmit these 15 messages.

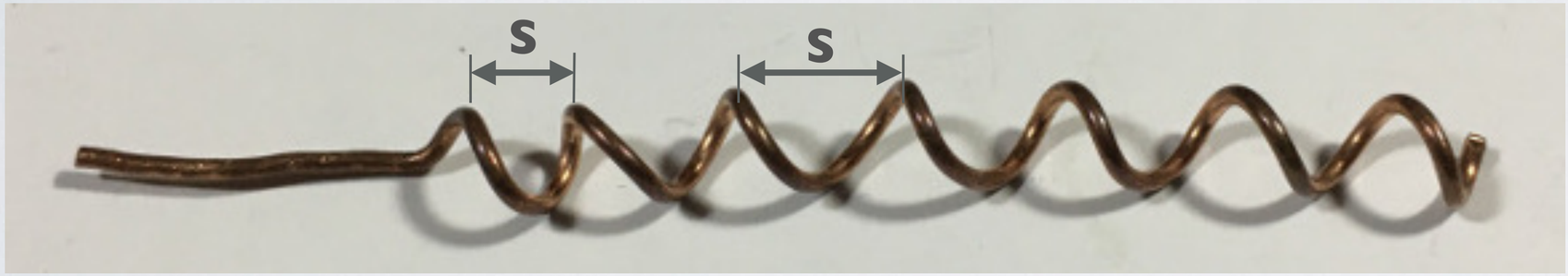
ANTENNA TEST RESULTS

- Looking at the results I can conclude that my self build normal mode helical antenna with ground plane performs the same as the sleeve dipole antenna.

- The normal mode helical antenna without a ground plane does not have a good antenna performance. I have drawn the same conclusion in tutorial 42 when demonstrating the ¼λ monopole antenna without a ground plane.

RECOMMENDATION

- A normal mode helical antenna is impossible to build accurately by hand.



- If you have to choose between a normal mode helical antenna or just a monopole antenna, I would choose a monopole antenna, because a monopole is easier to make.

- But if a monopole does not fit inside a container, than try a normal mode helical antenna. These antennas are smaller in length.

RECOMMENDATION

- If your project allows you to use a sleeve dipole antenna (see tutorial 43) I would prefer using a sleeve dipole antenna above a monopole or normal mode helical antenna.

- A normal mode helical antenna behaves like ¼λ monopole antenna.
  Without a good ground plane the antenna will not perform well as explained in tutorial 42.

- If you use a ¼λ monopole antenna or normal mode helical antenna without a good ground plane the signal can be transmitted over a distance of 100 m or even more. But if the distance is increased the signal will be weaker with increase data package loss. This is based on my experiments and situation.